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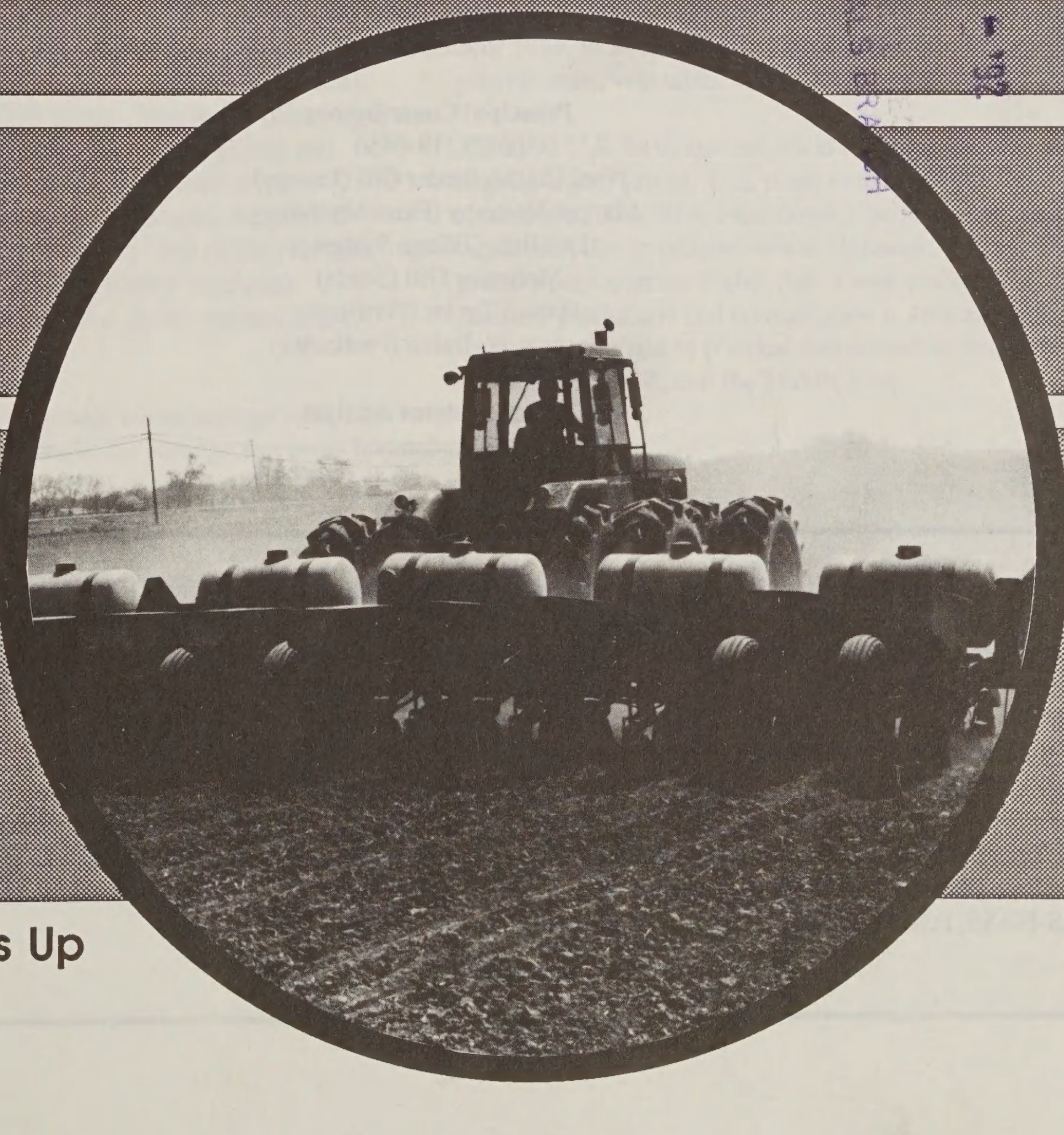

Pesticide Prices Up

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Contents

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Summary

Total 1991 pesticide use on the 10 major field crops is projected at 478 million pounds active ingredient (a.i.), up 15 million pounds from 1990. The area planted to row crops, which tend to be pesticide intensive, increased, while that for small grains decreased. Average farm-level herbicide prices rose 8.6 percent and insecticide prices rose 13 percent. Pesticide manufacturers' costs have increased because of the need to develop additional data to reregister older products, and to research and develop new products. Dealers' costs have also risen, especially for liability insurance.

U.S. farmers can expect energy prices through 1992 to be slightly above the 1991 average, due to expected steady or modestly higher prices for imported crude oil. Direct energy expenditures are expected to grow 3.3 percent to $7.72 billion in 1991. This can be attributed to the expected rise in energy prices, slightly offset by reduced fuel use associated with a small reduction in planted acreage for major field crops.

The forecast for 1991 unit sales of farm machinery has been revised downward, reflecting the expected slowdown in tractor sales to near 1990 levels. Weaker farm machinery sales can be linked to 1991 net farm income, which is forecast to fall about one tenth from 1990 levels. This is due primarily to reduced cash grain production, lower dairy prices, and slightly higher production expenses. However, some economic factors are encouraging. Farm asset values will likely show a significant increase by the end of the year and interest rates are down for farm machinery purchases. Receipts for some farm commodities, such as cotton and fruit, are rising.

Tillage systems used on 1991 winter wheat acreage varied little from 1990. About 16 percent of the acreage was produced with conservation tillage methods, 13 percent was mulch-till and 3 percent was no-till. Nearly 72 percent wasconventional tillage without the moldboard plow, reflecting chisel plow use in the normal wheat-fallow rotations of the arid western States. An average of 30 percent of the winter wheat acreage was highly erodible land. Over 90 percent of the 1990 fall potato production utilized conventional tillage methods. Some mulch tillage was used in the more western States, probably to help conserve moisture.

For the 1990/1991 crop year seed use for the eight major crops was estimated at 5.9 million tons, down 4 percent from the previous year. This decline resulted from lower wheat acreage planted, which fell 9 percent. Higher corn, grain sorghum, cotton, and soybean seed prices were offset by generally lower small grain, forage, and potato seed prices. As a result, USDA's prices-paid index for seed remained unchanged from last year. Changes between 1990 and 1991 tended to mirror price changes in the underlying commodities. Farm seed expenditures in 1990 rose only 1 percent from 1989, while 1991 expenditures are expected to increase 3 percent due to higher row-crop acreage, especially corn. The 1990 net seed trade surplus surged 30 percent over 1989, to $443 million. The increase primarily reflected gains in corn, vegetable, forage, and flower seed exports.

The 1992 U.S. fertilizer outlook is for adequate supplies at slightly higher prices. U.S. plant nutrient use in 1990/91 is estimated at 20 million tons, down 3 percent from the previous year, due to reduced wheat plantings. Spring 1991 prices were 4 percent higher than a year earlier. Worldwide fertilizer production and consumption is anticipated to decline in response to political and economic events in Eastern Europe, USSR, and the Middle East.

Energy

U.S. farmers can expect energy prices through 1992 to remain at or slightly above the 1991 average to date due to expected steady or modestly higher prices for imported crude oil. Direct energy expenditures (which comprise about 5.9 percent of total direct farm production expenses) are expected to grow 3.3 percent to $7.72 billion. This change can be attributed to the rise in energy prices slightly offset by reduced fuel use associated with a minimal reduction in planted acreage for the major field crops.

The World Crude Oil Price

After the Persian Gulf War, the world price of crude oil has settled back to the pre-war level of around $20 per barrel, although it rose for the few days surrounding the July aborted coup in the USSR (which is a major world producer of crude oil). The trend over the next few years, however, will evolve from a number of inherent uncertainties. These include the excess production capacity of the Organization of Petroleum Exporting Countries (OPEC), excess petroleum stocks relative to petroleum demand (as measured in days of forward consumption), and exports from the USSR.

The excess OPEC production capacity will be affected by the speed with which Iraq and Kuwait restore their oil production and exports. In general, a lower level of excess oil production capacity will place upward pressure on prices but this can be offset, at least partially, by abnormally high petroleum stocks. Soviet oil exports will be determined by the political stability in the oil producing regions and by the relative decline rates of both oil production and consumption, all of which are extremely uncertain at this time. In addition to these three factors, another uncertainty affecting the world oil price is world economic growth.

Given these uncertainties, the world price of crude oil is forecast by the Department of Energy to increase between 0 and 15 percent through the end of 1992, with the most probable increase being around 5 percent.

Domestic Petroleum Consumption and Production

The Department of Energy has analyzed the consumption and production of refined petroleum products, assuming an average world price of crude oil of $20 per barrel through 1992 (table 1). With a higher world crude oil price and a sluggish, though rebounding, economy, U.S. petroleum demand is expected to increase. At a world price of $20 per barrel, the demand for all refined petroleum products in 1992 is expected to be 16.92 million barrels per day, a 2.1 percent increase from the projected 1991 level.

On the supply side, the $20-per-barrel price is expected to slow, but not reverse, the rate of decline in domestic crude oil production in 1992. Crude oil imports growth are expected to reverse their direction from a decrease of 7.4 percent for 1991 to a 9.6 percent increase for 1992, as a result of reduced domestic production and increased domestic consumption. In 1992, total net petroleum imports are projected to once again increase by about 10 percent, after registering declines in 1990 and 1991.

Table 1--U.S. petroleum consumption-supply balance

Item	1988	1989	1990	Forecast 1991	Forecast 1992
	Million barrels/day				
Consumption:					
Motor gasoline	7.34	7.33	7.23	7.16	7.16
Distillate fuel	3.12	3.16	3.02	2.95	3.13
Residual fuel	1.38	1.37	1.23	1.13	1.10
Other petroleum 1/	5.45	5.47	5.51	5.34	5.53
Total	17.29	17.33	16.99	16.58	16.92
Supply:					
Production 2/	10.51	9.91	9.70	9.77	9.54
Net crude oil and petroleum imports (includes SPR) 3/	6.59	7.20	7.17	6.64	7.28
Net stock withdrawals	0.19	0.21	0.12	0.17	0.10
Total	17.29	17.32	16.99	16.58	16.92
	Percent				
Net imports as a share of total supply	38.11	41.57	42.20	40.05	43.03
	% change from previous year				
Consumption		0.23	-1.96	-2.41	2.05
Domestic production		-5.71	-2.12	0.72	-2.35
Imports		9.26	-0.42	-7.39	9.64

1/ Includes crude oil product supplied, natural gas liquid (NGL), other hydrocarbons and alcohol, and jet fuel. 2/ Includes domestic oil production, NGL, and other domestic processing gains (i.e., volumetric gain in refinery cracking and distillation process). 3/ Includes both crude oil and refined products. SPR denotes Strategic Petroleum Reserves.

Source: U.S. Department of Energy, Energy Information Administration. Short-Term Energy Outlook. DOE/EIA-0202(91/3Q). August 1991.

In the $20-per-barrel-world-oil case, the price of crude oil is assumed to increase by nearly $1 per barrel (2.4 cents per gallon) from the third quarter of 1991 to the fourth quarter of 1992. Most refined petroleum product prices would increase by about 3 cents per gallon during this period, indicating that the refiner margin would change little from the year earlier.

Unrelated to events in the world oil market, retail gasoline prices were up in mid-1991 due to relatively low inventories. This increase is expected to dissipate later in 1991 as stock levels rise to within their normal range.

At $20 per barrel, the consumption of most refined petroleum products is expected to remain constant for the remainder of 1991 and then increase slightly in 1992. In the transportation sector, continued slow economic growth and higher prices for gasoline and diesel fuel are expected to dampen travel demand. Growth in motor vehicle-miles traveled is expected to be more than offset by the continued

improvements in vehicle efficiency that yield declining use of gasoline and diesel fuel. Higher fuel costs are expected to result in higher airline ticket prices, which in turn is expected to keep commercial jet fuel demand weak in 1992.

The slightly higher energy prices are expected to have minimal effect on domestic production of crude oil in 1992. In a $20-per-barrel oil price scenario, domestic crude oil output is projected to decline in 1992 by 230,000 barrels per day from 1991 levels. This compares to an average increase of 70,000 barrels per day in 1991 but a decline of 210,000 barrels per day in 1990. Higher oil prices are expected to further slow the rate of decline in domestic crude oil production by the end of 1992.

At $20 per barrel, net imports of crude oil are anticipated to increase by 640,000 barrels per day to 7.28 million barrels per day in 1992, compared to an projected decline of 530,000 barrels per day in 1991. The expected 1992 increase largely reflects the reduced import rates during the first quarter of 1991 giving a lower base level of imports.

End-of-year crude oil inventories are projected to remain almost unchanged in both 1991 and 1992. The sizeable stock draw during the second half of 1990 and first quarter of 1991, brought about by the disruption of normal supply patterns, is projected to be reversed. Inventories should return to normal levels. Refined petroleum product inventories, however, are expected to increase slightly in 1992 over 1991.

Energy in the Farm Sector

The U.S. agricultural sector's energy supply and price expectations reflect world crude oil market conditions. Current world oil supplies are adequate and this situation is expected to continue into 1992. Fuel prices in the farm sector increased in 1990 from 1989, but are expected to stabilize in 1991-1992 at or slightly below 1990 levels. Farmers can expect plentiful supplies of gasoline, diesel fuel, and liquefied petroleum (LP) gas for the rest of 1991 and into 1992.

Little shift is expected in the input mix (e.g., fuel choice) over the next year. In the intermediate to long term, however, if crude oil prices go higher, farmers will likely substitute relatively less expensive energy (e.g., natural gas) for refined petroleum products where possible.

Farm Fuel Use

The consumption of refined petroleum products such as diesel fuel, gasoline, and liquefied petroleum gas by agriculture declined steadily between 1978 and 1989. Since then, aggregate energy consumption has remained relatively constant. Although the number of acres planted influences farm energy use, so do weather and other factors. For example, the switch from gasoline to diesel-powered engines; adoption of conservation tillage practices; change to larger, multifunction machines; and innovations in crop drying and irrigation contributed to the earlier decline. While no-till and mulch-till farming practices have not yet been widely adopted, they are now as prevalent as conventional tillage practices in some parts of the United States.

With only a minimal decrease in total acres planted and harvested in 1991, few significant changes in cropping practices, and somewhat higher average energy prices for the entire growing season, the data, when available (in 1992), are expected to show that 1991 farm energy consumption remained near its 1990 level.

Energy Prices Rose in 1990 and Fell in Early 1991

Crude oil prices (especially that of imported crude, since it is the marginal supply in most instances) heavily influence the prices farmers pay for refined petroleum products. Historically each 1 percent increase in the price of imported crude oil in the United States has translated into about a 0.7 percent rise in the price of gasoline and diesel fuel paid by farmers. In 1990, average gasoline prices increased by 11.4 percent and diesel fuel prices rose by 25 percent over their 1989 levels (table 2). Through July 1991, gasoline prices are approximately at their 1990 average level while diesel fuel prices have fallen 7.4 percent below their 1990 level.

More revealing than average energy prices between 1990 and 1991 are the prices as they changed between July and October of 1990 and January, April, and July of 1991. Recall that the Persian Gulf War began on August 2, 1990. Thus, between July 1990 and October 1990 when the impact of the conflict on the world crude oil market was most

Table 2--Average U.S. farm fuel prices 1/

Year	Gasoline	Diesel	LP gas
		$/gallon 2/	
1981	1.29	1.16	0.70
1982	1.23	1.11	0.71
1983	1.18	1.00	0.77
1984	1.16	1.00	0.76
1985	1.15	0.97	0.73
1986	0.89	0.71	0.67
1987	0.92	0.71	0.59
1988	0.93	0.73	0.59
1989	1.05	0.76	0.58
1990	1.17	0.94	0.83
Jan 1990	1.09	1.01	1.06
April 1990	1.08	0.81	0.67
July 1990	1.10	0.74	0.65
Oct 1990	1.41	1.22	0.94
Jan 1991	1.26	1.05	0.88
April 1991	1.16	0.82	0.72
July 1991	1.16	0.77	0.68

1/ Based on surveys of farm supply dealers conducted by the National Agricultural Statistics Service, USDA. 2/ Bulk delivered.

Table 3--Farm energy expenditures

Item	1987	1988	1989	1990	Forecast 1991
			$ billion		
Fuels and lubricants:					
Gasoline	1.37	1.42	1.44	1.65	1.62
Diesel	2.13	2.12	2.12	2.42	2.57
LP gas	0.38	0.38	0.38	0.53	0.56
Other	0.47	0.53	0.51	0.57	0.60
Electricity:					
Excluding irrigation	2.03	2.17	1.69	1.65	1.70
For irrigation	0.43	0.48	0.64	0.65	0.67
Total	6.81	7.10	6.78	7.47	7.72
Percent change from preceding year		4.25	-4.51	10.18	3.35

Source: U.S. Department of Agriculture, National Agriculture Statistics Service, Farm Production Expenditures, 1987, 1988, 1989, and 1990 summaries.

severely felt, the price of gasoline, diesel fuel, and LP gas jumped by 28.1 percent, 65.9 percent, and 44.6 percent, respectively. As surge production from oil producing countries replaced that lost from Iraq and Kuwait, the world price decline resulted in a fall in average U.S. farm fuel prices (table 2). After the cessation of hostilities in February 1991, the price of gasoline stabilized slightly above pre-War levels, while prices of diesel fuel and LP gas approached their pre-War level.

Energy Expenditures Up in 1990

In 1990, farm energy expenditures on gasoline, diesel fuel, LP gas, electricity, natural gas, and lubricants totaled $7.47 billion, up 10.2 percent from a year earlier (table 3). This rise reflects a 20.2 percent jump in fuel and lubricant expenditures and about a 3.0 percent increase in electricity expenditures. Higher energy prices, higher yields and a very slight fall in the number of acres planted and harvested in 1990 over 1989 accounted for these increases. For 1991, a moderate loss in planted acreage coupled with relatively higher energy prices during the planting season are projected to hold the rise in farm energy expenditures to just 3.3 percent.

Farm Machinery

Nominal expenditures for tractors and other farm machinery rose an estimated $510 million in 1990 to $8.2 billion (table 4). However, expenditures in 1991 may not exceed those of

Table 4--Trends in U.S. farm investment expenditures and factors affecting farm investment demand

Item	1984	1985	1986	1987	1988	1989	1990	Forecast 1991
				$ billion				
Capital expenditures:								
Tractors	2.54	1.94	1.51	2.10	2.48	2.76	2.87	2.7-3.0
Other farm machinery	4.68	3.23	3.09	4.30	4.15	4.92	5.32	5.2-5.5
Total	7.22	5.17	4.60	6.40	6.63	7.68	8.19	7.9-8.5
Tractor and machinery repairs	3.59	3.44	3.43	3.51	4.56	3.93	3.73	3.7-4.0
Trucks and autos	2.04	1.76	1.71	2.17	2.33	2.50	2.81	2.3-2.6
Farm buildings 1/	3.26	2.26	2.14	2.60	2.35	2.45	2.67	2.5-2.9
Factors affecting demand:								
Interest expenses	21.1	18.6	17.1	15.1	14.8	14.7	14.7	14-16
Total production expenses	141.6	132.4	125.5	128.6	133.5	140.5	144.8	145-150
Outstanding farm debt 2/ 3/	204	188	167	154	149	146	145	143-149
Farm real estate assets 2/	735	757	613	659	687	693	703	715-725
Farm nonreal estate assets 2/	241.5	235.8	234.9	253.2	270.0	283.4	293.5	295-305
Agricultural exports 4/	38.0	31.2	26.3	27.9	35.3	39.6	40.2	37
Cash receipts	142.8	144.1	135.2	141.6	151.0	160.5	169.1	166-171
Net farm income	26.3	31.0	31.0	39.7	41.0	49.2	49.6	41-46
Net cash income	36.6	47.9	46.7	55.3	57.4	58.3	59.7	54-59
Direct government payments	8.4	7.7	11.8	16.7	14.5	10.9	9.3	8-9
				Million acres				
Diverted acres 5/	27.0	30.7	48.1	76.2	77.7	60.8	61.6	63.3
				Percent				
Real prime rate 6/ 7/ 8/	8.3	6.9	5.7	5.0	6.0	6.8	5.9	4.7
Nominal farm machinery and equipment loan rate 8/	14.6	13.7	12.2	11.5	11.7	12.8	12.3	11.4
Real farm machinery and equipment loan rate 7/ 8/	10.8	10.7	9.4	8.3	8.4	8.7	8.2	8.5
Debt-asset ratio 9/	19.8	21.0	19.6	16.9	15.5	15.0	14.6	14-15

1/ Includes service buildings, structures, and land improvements. 2/ Calculated using nominal dollar balance sheet data, including farm households for December 31 of each year. 3/ Excludes CCC loans. 4/ Fiscal year. 5/ Includes acres idled through commodity programs and acres enrolled in the Conservation Reserve Program. 1991-preliminary. 6/ Monthly average. 7/ Deflated by the GNP Deflator. 8/ Average annual interest rate. From the quarterly sample survey of commercial banks: Agricultural Financial Databook, Board of Governors of the Federal Reserve System. Interest for 1991 is for second quarter. 9/ Outstanding farm debt (including households) divided by the sum of farm real and nonreal estate asset values.

Source: Agricultural Income and Finance, Situation and Outlook Report AFO-41, ERS; and other ERS sources.

Table 5--Domestic farm machinery unit sales

Machinery category	1985	1986	1987	1988	1989	1990	Forecast 1991	Change 89-90	Change 90-91
				Units				Percent	
Tractors:									
Two-wheel-drive									
40-99 hp	37,800	30,800	30,700	33,200	34,900	38,400	38,900	10	1
100-139 hp 1/	7,300	5,100	5,100	4,300	5,200				
Over 139 hp 1/	10,400	9,100	10,800	11,800	15,400				
Total over 99 hp	17,700	14,300	15,900	16,100	20,600	22,800	23,300	11	2
Four-wheel-drive	2,900	2,000	1,700	2,700	4,200	5,100	5,200	23	2
Grain and forage harvesting equipment:									
Self-propelled combines	8,400	7,700	7,200	6,000	9,100	10,400	11,300	15	8
Forage harvesters 1/2/	2,500	2,200	2,300	2,400	2,800				
Haying equipment:									
Mower conditions 1/	11,200	10,900	11,200	11,000	13,200				

1/ Discontinued after 1989. 2/ Shear bar type.

Source: Equipment Manufacturers Institute (EMI). All 1991 values are ERS forecasts.

1990. Both net cash and farm income are forecast to decrease in 1991 due to declining cash grain production, lower dairy prices, and increasing production expenses. Net farm income is forecast to fall about 10 percent. Direct government payments will not increase. Agricultural commodity exports will likely show a $3 billion decrease from the $40.2 billion in 1990. Outstanding farm debt will likely climb in 1991, reversing a 7-year downward trend. Diverted acres (idled through commodity programs or enrolled in the Conservation Reserve Program) increased in 1991 from 61.6 to 63.3 million acres, which may further reduce machinery demand.

Offsetting these factors is the continued improvement of farm asset values in 1990 and 1991. With both debt and asset values increasing, the debt-asset ratio will probably remain stable at 15; well below the 1985 high of 21. Also, interest rates for farm machinery fell from the 1990 rate of 12.3 percent to a second-quarter 1991 rate of 11.4 percent.

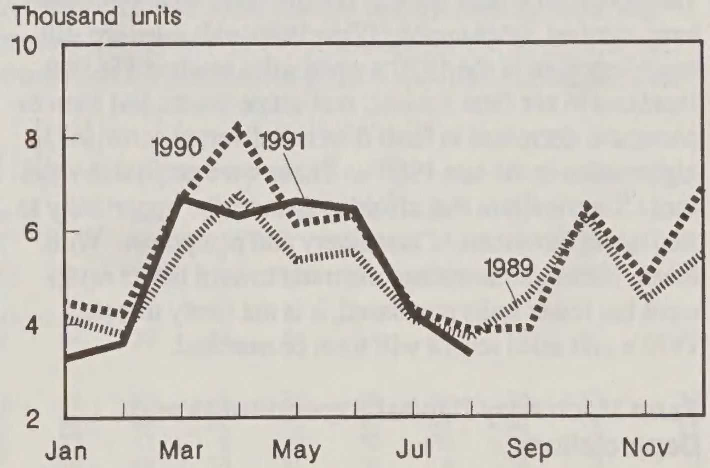
Land Values Increase

Land values continued recovery with a nominal, 2 percent rise in 1990 and are forecast up 1 to 3 percent in 1991. Land value increases are the major component of higher real estate values and can reflect heightened expectations of farm profitability. Higher asset values improve the equity position of farm owners and help in financing machinery purchases. Real (inflation-adjusted) land values, however, were down in 1990 and are forecast to decrease from 0 to 4 percent in 1991, suggesting that a sustained recovery of real land values has not yet occurred.

Interest Rates Decrease

The real farm machinery and equipment loan rate fell to 8.2 percent in 1990. However, this loan rate was up three tenths of a percent by the end of the second quarter of 1991 (table 4). The nominal farm machinery loan rate, the one that probably more directly affects farmers' decisions to purchase, decreased for the third consecutive year to 11.4 percent in the second quarter of 1991.

Figure 1
Farm Tractor Sales[1]



1/ Wheel tractors 40 horsepower and above.
Source: Equipment Manufacturers Institute.

Unit Sales

Increases in unit sales of new farm machinery in 1990 occurred in all categories (table 5). Combine sales, for example, rose 15 percent. The number of combines sold is forecast to increase another 8 percent by the end of 1991. Increases in sales of tractors and combines reflect recovery from the depressed sales levels of the early and mid 1980's. Monthly sales of tractors through July 1991 have generally lagged behind those for 1990 (figure 1). Monthly sales of tractors will likely pick up through October and December, in line with seasonal trends of previous years. A 2 percent average increase over 1990 is forecast in the sales of tractors and combines by the end of 1991.

Tractor Sales

Sales of tractors in the higher horsepower ranges continued to increase as a proportion of all farm tractor sales. In 1990, four-wheel-drive tractors were 7.7 percent of sales, compared with 7 percent in 1989 and only 3 percent in 1987. Generally, for the last 20 years, the proportion of four-wheel-drive tractor sales increased when total farm machinery sales increased, and decreased when farm income declined and total tractor sales fell.

Increased sales of larger tractors is probably due in part to a trend toward larger farms. The U.S. Department of Agriculture (Agricultural Statistics, 1990) reported a 12 percent decrease in the number of farms since 1977. Average farm size increased from 427 to 461 acres. Larger tractors handle larger implements and can cover more ground per pass. The increased sales of larger tractors suggest that farmers find them more cost-effective than smaller tractors.

Though sales of farm tractors (greater than 40 horsepower) have climbed, reaching 66,000 in 1990, unit sales are still much less than in the 1970's when sales reached 156,000. Increases in net farm income, real estate assets, and farm exports; and decreases in farm debt and diverted acres, led to higher sales in the late 1980's. These were profitable years for U.S. agriculture that afforded farmers the opportunity to step up replacements of machinery and equipment. With fewer, but larger farms and the trend toward larger equipment but fewer units purchased, it is not likely that the 1970's unit sales record will soon be matched.

Farm Machinery Capital Expenditures and Depreciation

Depreciation exceeded capital expenditures every year during the 1980's for farm machinery in the United States. Known as capital depletion, this phenomenon was pronounced in the mid 1980's when real depreciation reached $8.5 billion and real capital expenditures were $4.2 billion. The gap narrowed to $1.3 billion in 1989. When the final figures are available for 1991, real capital expenditures probably will again exceed real depreciation.

While continued, long term, capital depletion could have serious implications for both the farming sector and the farm machinery supply sector, capital depletion in the 1980's is likely the result of farmers' adjustments to cyclical economic conditions. The profitable farming years of the mid to late 1970's encouraged farmers to buy tractors and machinery, sometimes more and larger units than needed. When farm income declined in the early 1980's, farmers bought less machinery, but the farming sector remained highly productive by keeping old machinery in repair and using extra capacity built up during the late 1970's. Although delaying expenditures on farm machinery can incur higher repair costs, there is usually a range of years when the difference in cost between keeping an old machine and buying a new one is small.

Farm Machinery Foreign Trade

Revised farm machinery trade data for 1990 show exports of farm and garden machinery and equipment still exceeding imports. Exports in 1990 were $3.4 billion, compared to $2.8 for imports, leaving a net positive balance of $629 million, according to the U.S. International Trade Commission. This was down from $746 million in 1989. Manufacturers' shipments were $9.8 billion in 1990. Accounting for imports and exports, apparent U.S. consumption was $9.2 billion with about 30 percent of farm and garden machinery and equipment supplied by imports.

The United States had farm machinery trade with over 130 countries in 1990. The major share of exports went to Canada (33 percent), Mexico (8 percent), Australia (7 percent), and France (6 percent). The U.S. imported farm machinery from Canada (20 percent), Germany (20 percent), the United Kingdom (17 percent), Japan (14 percent) and Italy (6 percent). The U.S. had a farm machinery trade deficit with Germany (-$404 million), the United Kingdom (-$307 million), Japan (-$243 million), and Italy (-$132 million).

Tillage Systems

Tillage operations and amount of previous crop residue on the soil surface after planting are important indicators of soil erosion potential. The conservation compliance provisions of the 1985 Food Security Act (FSA) require farmers to implement conservation practices on highly erodible land (HEL) by 1995 or become ineligible for farm program benefits. To meet these requirements, a change in crop rotation, different tillage system, addition of a cropping practice (such as contouring), and/or installation of permanent structures are recommended. The USDA has developed plans for 135 million acres of highly erodible cropland. These plans include 100 million acres of conservation tillage in the recommendations.

For water erosion control purposes, a conservation tillage system is defined as one that leaves 30 percent or more of the soil surface covered with residue after planting. Conventional tillage methods (with and without the moldboard plow) leave less than 30 percent. Since the various tillage systems leave significantly different residue levels, the type of system directly affects erosion potential and water quality. In general, conventional tillage systems without the moldboard plow leave less than one-half as much residue after planting as mulch-till systems.

The tillage system employed influences the types and levels of other input use. Labor hours spent in tilling the soil are related to the number of times the farmer goes over the field, as well as implement size and tractor speed. Labor and fuel are normally reduced with tillage systems that require fewer trips over the field. On the other hand, a no-till system used on sod might necessitate an extra trip for an herbicide applied to kill vegetation.

Tillage system designations were determined from estimates of residue remaining after planting and the use of specific implements (1). To obtain the residue estimate, the percent of residue remaining was estimated from the previous crop and reduced by the residue incorporation rate of each tillage and planting implement used. For this report, the percent of residue was assumed to be evenly distributed over the soil surface.

1991 Winter Wheat

Oregon reported the heaviest reliance on the moldboard plow among major winter wheat producing States in the 1991 Cropping Practices Survey (table 6). According to Extension personnel, some western producers believe that the risk of disease is intensified when large amounts of wheat residue are left on the soil surface. Many of these states follow a wheat-fallow or a wheat-wheat-fallow rotation. Idaho and South Dakota reported that mulch tillage was used on more than 20 percent of winter wheat acreage. Indiana and Ohio reported 18 and 13 percent use of no-till, respectively. These States often plant winter wheat after fragile residue soybeans (2). Compared to 1990 acreage, proportional use of the moldboard plow and no tillage remained unchanged, while conventional tillage without the plow increased slightly at the expense of mulch till.

South Dakota and Indiana had the highest estimated percent residue remaining after planting (27 and 25 percent) because of extensive use of mulch-till and no-till methods. Oklahoma had the lowest (10 percent) because of greater use of conventional tillage methods. There was little change in average residue levels from 1990.

A slight increase in the number of trips over the field was reported, compared to 1990. Except for the no-till system, wheat acreage has more trips over the field than most other

Table 6--Tillage practices used in winter wheat production, 1991 1/

Category	AR	CO	ID	IL	IN	KS	MO	MT	NE	OH	OK	OR	SD	TX	WA	Area
Harvested acres (1000)	930	2300	700	1400	750	10800	1550	1900	2100	1100	5000	800	1300	2800	750	34180
							percent of acres 2/									
Highly erodible land	4	50	43	28	25	31	29	61	30	12	16	34	32	19	52	30
Tillage system:																
Conv/w mbd plow 3/	id	6	10	id	id	18	id	nr	20	9	22	30	nr	id	15	12
Conv/wo mbd plow 4/	87	77	59	77	70	65	82	84	69	72	73	60	69	86	72	72
Mulch-till 5/	id	16	22	11	9	17	10	13	11	6	5	10	25	12	8	13
No-till 6/	9	id	9	9	18	id	7	id	nr	13	nr	nr	6	id	5	3
						percent of soil surface covered										
Residue remaining after planting:																
Conv/w mbd plow	id	2	2	id	id	2	id	nr	2	2	2	2	nr	id	2	2
Conv/wo mbd plow	11	17	10	17	16	14	18	15	14	14	11	18	17	10	14	14
Mulch-till	id	40	40	38	42	36	40	40	35	32	39	38	43	42	38	[illegible]
No-till	66	id	39	61	58	id	55	id	nr	54	nr	nr	72	id	42	57
Average	17	20	18	23	25	16	22	20	14	19	10	15	27	14	16	17
								Number								
Hours per acre:																
Conv/w mbd plow	id	.6	.7	id	id	.7	id	nr	.7	1.0	.8	.7	nr	id	.7	.7
Conv/wo mbd plow	.3	.4	.4	.3	.3	.6	.4	.4	.6	.5	.6	.5	.4	.6	.6	.5
Mulch-till	id	.4	.4	.2	.2	.4	.3	.2	.5	.3	.4	.4	.2	.4	.5	.4
No-till	.1	id	.1	.1	.2	id	.2	id	nr	.1	nr	nr	.1	id	.1	.1
Average	.3	.4	.4	.3	.3	.6	.4	.3	.6	.4	.6	.5	.4	.6	.6	.5
Times over field:																
Conv/w mbd plow	id	5.8	3.9	id	id	5.7	id	nr	6.8	3.9	5.4	5.5	nr	id	5.7	5.6
Conv/wo mbd plow	3.5	6.3	3.2	2.6	2.4	5.9	2.9	4.8	5.7	2.7	5.2	6.1	5.4	5.3	5.6	5.0
Mulch-till	2.0	4.6	3.4	2.0	2.0	4.9	2.1	2.8	4.4	2.0	4.2	4.8	3.2	4.2	5.3	4.2
No-till	1.0	id	1.0	1.0	1.0	id	1.0	id	nr	1.0	nr	nr	1.0	id	1.0	1.0
Average	3.3	5.9	3.1	2.4	2.2	5.6	2.7	4.4	5.8	2.5	5.2	5.8	4.6	5.1	5.4	4.9

id = Insufficient data. nr = None reported.

1/ Preliminary. 2/ May not add to 100 due to rounding. 3/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 4/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 5/ Mulch-tillage--System that has 30 percent or greater remaining residue after planting and is not a no-till system. 6/ No-tillage--No residue-incorporating tillage operations performed prior to planting; does allow passes of nontillage implements, such as stalk choppers.

field crops. Much of the wheat produced in the Great Plains and western States is produced after a fallow period (2). All implement trips over the field made during the fallow year were included in determining residue levels. Typical fallow procedure starts in the fall with chisel plowing and other non-inversion tillage operations, instead of a single pass with the moldboard plow. For these States, therefore, the tables reflect more trips over the field under conventional tillage without the moldboard plow.

An average of 30 percent of the 1991 surveyed winter wheat acres were produced on highly-erodible fields. This figure varied from about 4 percent in Arkansas to 50 percent or more in Montana, Washington, and Colorado. The western States are usually more subject to wind erosion than to water erosion. A greater proportion of acreage may be affected because wind erosion is not limited to the more sloping soils.

Conventional tillage methods were used on 82 percent of the highly erodible acreage, with 8 percent using the moldboard plow and 74 percent not using the plow. Some of these acres likely meet conservation compliance requirements because the entire rotation, timing of tillage operations, and other practices are used in the evaluation. The majority of western winter wheat producers follow a wheat-fallow rotation. They usually begin the fallow period by roughening the soil by chisel or sweep plowing, leaving residue on the soil surface. This not only decreases wind erosion but helps retain water. Winter wheat is planted the following fall and plant growth provides protection during the next spring's period of highest wind erosion.

1990 Potatoes

In 1990 fall potato production, Pennsylvania farmers used the moldboard plow on 95 percent of acreage (table 7). New York, Michigan, and Wisconsin also reported use of the plow on over 60 percent of acreage. In most other surveyed States the plow was used on less than 40 percent of the acres. Oregon, Idaho, and North Dakota reported the largest use of conventional till without the moldboard plow (over 60 percent). No tillage is still not a common practice among potato growers. In rotations emphasizing potatoes, any decaying vines or tubers left in the fields from previous years may harbor the organisms for early or late blight. In many States, remaining residue averaged less than 10 percent. For all potato production, there was an average of more than four tillage passes.

Table 7--Tillage practices used in fall potato production, 1990

Category	CO	ID	ME	MI	MN	NY 1/	ND	OR	PA	WA	WI	Area
Planted acres (1000) 2/	66	395	81	34	69	23	145	53	23	129	69	1087
					percent of acres 3/							
Highly erodible land	55	33	17	0	5	5	14	39	22	41	6	24
Tillage system:												
Conv/w mbd plow 4/	41	31	31	65	38	79	11	23	95	40	60	35
Conv/wo mbd plow 5/	50	68	53	30	56	17	60	72	5	52	29	56
Mulch-till 6/	9	1	16	3	6	nr	29	6	nr	8	9	8
No-till 7/	nr	nr	nr	id	nr	id	nr	nr	nr	nr	id	id
					percent of soil surface covered							
Residue remaining after planting:												
Conv/w mbd plow	1	1	1	1	2	2	2	1	2	2	2	2
Conv/wo mbd plow	9	9	10	12	19	14	15	8	9	12	15	11
Mulch-till	46	44	42	36	36	nr	39	35	nr	42	43	41
No-till	nr	nr	nr	id	nr	id	nr	nr	nr	nr	id	47
Average	9	7	13	7	14	6	21	8	2	10	10	10
					Number							
Hours per acre:												
Conv/w mbd plow	.8	.9	1.1	1.0	.6	1.5	.4	2.1	1.3	1.1	.8	1.0
Conv/wo mbd plow	.7	.8	.9	.8	.5	1.3	.4	1.3	1.7	.8	.5	.7
Mulch-till	.4	.4	.7	.5	.4	nr	.3	.8	nr	.5	.4	.4
No-till	nr	nr	nr	id	nr	id	nr	nr	nr	nr	id	.2
Average	.7	.8	.9	.9	.5	1.4	.4	1.5	1.3	.9	.7	.8
Times over field:												
Conv/w mbd plow	4.2	4.3	3.9	4.2	3.8	4.0	4.1	6.1	3.7	4.6	3.1	4.1
Conv/wo mbd plow	4.3	4.7	3.4	3.4	4.1	4.1	4.3	5.2	4.3	4.3	3.4	4.4
Mulch-till	2.2	3.0	2.8	2.5	3.4	nr	2.9	3.3	nr	2.2	2.4	2.8
No-till	nr	nr	nr	1.0	nr	1.0	nr	nr	nr	nr	1.0	1.0
Average	4.1	4.5	3.5	3.8	3.9	3.4	3.9	5.3	3.7	4.2	3.1	4.2

id = Insufficient data. nr = None reported.

1/ Excludes Long Island. 2/ Preliminary. 3/ May not add to 100 due to rounding. 4/ Conventional tillage with moldboard plow--any tillage system that includes the use of a moldboard plow and has less than 30 percent residue remaining after planting. 5/ Conventional tillage without moldboard plow--any tillage system that has less than 30 percent remaining residue and does not use a moldboard plow. 6/ Mulch-tillage--System that has 30 percent or greater remaining residue after planting and is not a no-till system. 7/ No-tillage--No residue-incorporating tillage operations performed prior to planting; does allow passes of nontillage implements, such as stalk choppers.

Wind erosion is often a problem on the flat, loamy-sandy soils utilized for potato production. Therefore, many of these soils are designated highly erodible. Cover crops, such as rye, are often used as erosion protection in the eastern States where water availability is not a major problem. This may partially explain why in eastern States the moldboard plow is used more extensively. However, in other States, farmers will probably decrease the use of the moldboard plow and retain more crop residue in order to comply with erosion reduction objectives and conserve moisture.

References

1. Bull, Len. "Residue and Tillage Systems in 1987 Corn Production," *Agricultural Situation and Outlook Report*, AR-13, February 1989, pp. 36-41.

2. Gill, Mohinder and Daberkow, Stan. "Cropping Pattern-Comparisons Between 1989 and 1988," *Agricultural Situation and Outlook Report*, AR-21, February 1991, pp. 43-47.

Table 9--April farm planting seed prices 1/

Item	Unit	1989	1990	1991	Change 90-91
					Percent
Field seeds:					
Corn	2/	71.40	69.90	70.20	0
Grain sorghum	$/cwt.	69.50	69.90	71.20	2
Oats	$/bu.	5.89	4.19	3.71	-11
Barley	$/bu.	5.91	5.25	4.55	-13
Wheat (spring)	$/bu.	6.71	6.05	4.72	-22
Wheat (winter)	$/bu.	7.55	8.01	6.89	-14
Soybeans	$/bu.	14.70	12.50	12.80	2
Cotton	$/cwt.	50.10	54.30	58.20	7
Potatoes	$/cwt.	10.60	11.00	9.70	-12
Forage seeds:					
Red clover	$/cwt.	162.00	145.00	134.00	-8
Fescue, Tall 3/	$/cwt.	111.00	85.10	89.00	5
Orchardgrass	$/cwt.	117.00	102.00	101.00	-1
Ryegrass, annual	$/cwt.	54.30	50.50	46.80	-7
Timothy	$/cwt.	132.00	82.10	66.40	-19
Lespedeza, sericea	$/cwt.	167.00	134.00	101.00	-25
Alfalfa, proprietry	$/cwt.	249.00	253.00	266.00	5
Seed price paid index (1977=100)		170	163	163	0

1/ Derived from the April survey of farm supply dealers conducted by NASS, USDA. 2/ $/80,000 kernels. 3/ Alta, and Kentucky 31.

Seeds

Consumption

In the 1990/1991 crop year, seed consumption for eight major field crops will likely equal 5.9 million tons, a 4 percent decline from the previous year (table 8). This is because the planted aggregate acreage of these field crops is 1-2 percent lower than last year resulting primarily from a 9 percent decline in wheat acres.

Table 8--Seed use for major U.S. field crops 1/

Crops	1987/88	1988/89	1989/90	1990/91 2/	89/90-90/91
	1,000 tons				Percent
Corn	482	515	529	540	2
Sorghum	36	42	31	36	16
Soybeans	1,684	1,751	1,664	1,722	3
Barley	377	360	320	350	1
Oats	506	433	361	306	-15
Wheat	2,550	3,090	3,000	2,670	-11
Rice	150	150	160	160	0
Cotton 3/	93	112	94	108	15
Total	5,878	6,453	6,159	5,892	-4

1/ Crop marketing year. 2/ Preliminary. 3/ Upland cotton.

Prices

Higher corn, grain sorghum, cotton and soybean seed prices in 1991 were offset by generally lower small grain, and forage seeds, and seed potato prices. As a result, USDA's prices paid index for seed remained unchanged from last year.

Due to the substitutability of crop production between seed use and commercial disappearance, seed prices for most open-pollinated seeds are linked to the price of the underlying commodity. For example, soybean and cotton marketing year prices for 1990/91 were above those for 1989/90 leading to seed price increases of 2 and 7 percent, respectively. Conversely, spring wheat, winter wheat, oats, and barley seed prices fell 22, 14, 12, and 13 percent, respectively, between April 1990 and 1991 (table 9). Prices received by farmers for each of these commodities also declined between the 1989/90 and 1990/91 marketing years, reflecting the increased supply relative to demand. The correlation between seed and commodity prices is strengthened by farmers option to save seed from current production for the following year's crop.

Hybrid seed prices, such as for corn and grain sorghum, reflect several supply and demand factors. For example, the weather conditions that either inhibit or enhance yields of the commercial crop of corn and grain sorghum also affect the seed supply the following year. Furthermore, hybrid seeds are typically purchased rather than grown on the farm, which reduces farmers' seed source options.

During the 1988 drought, seed corn production was adversely impacted. With seed corn supplies down and planted corn acreage up in 1989, seed prices increased 11 percent. Seed supplies returned to normal by the spring of 1990, allowing prices to slip 2 percent despite a 2 million acre increase in planted corn. In 1991, seed corn prices increased less than 1 percent, even though planted corn acreage rose 1.7 million acres from 1990 levels. An increasing share of seed corn production has been contracted with producers who have irrigated land, thus reducing the risk of disruptive seed supplies.

Forage seed prices were generally lower this year compared to 1990, as demand declined due to slowing growth of Conservation Reserve Program (CRP) acreage. For example, timothy, annual ryegrass, red clover, and orchardgrass prices fell 19, 7, 8, and 1 percent, respectively. Only 565,000 acres were conditionally accepted by USDA in March of this year, compared to 4.1 million in 1990. About 550,000 are actually expected to be retired in 1991, because farmers whose bids were conditionally accepted, had the right to withdraw. In addition, 18 percent of the newly enrolled CRP acres will be planted to trees, whereas trees accounted for only 6 percent of the land enrolled in the previous sign-ups. This factor has also contributed to reducing grass seed demand. USDA has conditionally accepted another 1.12 million acres into CRP from 2.35 million that were bid in July. However, these acres will not be retired until 1992.

Seed Expenditures

In 1990, total farm seed expenditure was close to $4.0 billion— an increase of only 2 percent from 1989 (table 10). Field-crop and small-grain seed expenditures fell 4 percent in 1990 as prices for these seeds declined. However, expenditures for seeds and plants for other crops rose 31 percent in 1990 and offset the decline for field crops, small grains, legumes, grasses, and forage seeds. Farm seed expenditures are expected to rise slightly in 1991 due to increased planted corn and grain sorghum acreage.

Table 10--U.S.farm expenditures for seeds 1/

Item	1986	1987	1988	1989	1990	Change 89-90
	Billion dollars					Percent
Field crops and small grains	2.70	2.46	2.49	2.77	2.67	-4
Legumes, grasses, and forages	0.39	0.39	0.34	0.34	0.33	-2
Seeds and plants for other crops	0.37	0.65	0.78	0.67	0.88	31
Other seed expenses 2/	0.04	0.05	0.09	0.08	0.05	-37
Total seed expenditures	3.50	3.54	3.69	3.86	3.93	2

1/ Excludes bedding plants, nursery stocks, and seed purchased for resale. 2/ Includes seed treatment.

Source: U.S. Department of Agriculture, NASS. Farm Production Expenditures, 1990 Summary.

1990 Fall Potato Seeding Rates and Seeding Cost Per Acre

The average seeding rate for the 11 leading fall potato producing States in 1990 was 20 cwt per acre, the same as in 1988 and 1989 (table 11). However, potato seeding rates among States vary significantly due to moisture availability—either rainfall or irrigation — during the growing season. Maine and New York had higher seeding rates because of adequate rainfall. Washington, Oregon, and Colorado tend to have higher seeding rates because potatoes are irrigated. States with less rain and limited irrigation (such as North Dakota and Minnesota), have lower seeding rates. North Dakota with 15 cwt per acre, had the lowest seeding rate.

Table 11--Fall potato seeding rates, seed cost per acre, and percent purchased, 1990 1/

States	Acres planted 2/	Rate per acre	Cost per acre 3/	Acres with purchased seed
	1,000	Cwt	Dollars	Percent
Colorado	66	24	265	45
Idaho	395	20	207	89
Maine	81	21	233	64
Michigan	34	21	253	77
Minnesota	69	17	194	71
New York 4/	23	24	332	76
North Dakota	145	15	178	92
Oregon	53	21	247	92
Pennsylvania	23	19	251	94
Washington	129	22	278	98
Wisconsin	69	20	240	82
1990 Average	1,087	20	224	84
1989 Average	1,011	20	189	83
1988 Average	1,006	20	129	83

1/ States in survey planted 92 percent of the fall potato acreage in 1990. 2/ Preliminary. 3/ Based on data from those farmers who used purchased seed. 4/ Excludes Long Island.

Seeding rates and seed prices primarily determine seed cost per acre. In 1990, the average seed cost per acre was $224, up about 19 percent from a year earlier because of higher seed prices. Among States, variations in seed potato prices and seeding rates resulted in per acre cost ranging from $178 for North Dakota to $332 for New York. Average potato seed cost per acre in 1991 is likely to be lower than 1990, as average seed price fell 12 percent from year earlier level.

Farmers used purchased rather than homegrown seed potatoes on 84 percent of the 1990 fall potato acres. In Colorado, only 45 percent of the acres were planted with purchased seed, the lowest among potato growing States. Potato producers in Colorado tend to grow a large share of their own seed potatoes, which are one or two generations away from certified seed.

1991 Winter Wheat Seeding Rates and Seed Cost per Acre

The average seeding rate per acre was 74 pounds for winter wheat in 1991, while the average cost was $8.65 per acre (table 12). Seeding rates and costs, however, varied considerably among 15 surveyed States. Arkansas, Illinois, Indiana, Missouri, and Ohio had higher seeding costs, reflecting higher seeding rates per acre.

Indiana had the highest seeding cost although the seeding rate was second to the highest, indicating that these seeds are more costly than any other surveyed State. Colorado, on the other hand, had the lowest seeding rate and cost per acre. Farmers seeded 36 percent of the 1991 winter wheat acreage with purchased seed. Indiana showed the highest percent (79 percent) and Oklahoma the lowest (21 percent). Tradition, economic situation, and prices and yield of purchased seed apparently account for much of the regional variations.

Table 12--Winter wheat seeding rates, seed cost per acre, and percent of seed purchased, 1991 1/

States	Acres	Rate per acre	Cost per acre 2/	Acres with purchased seed
	Thousands	Pounds	Dollars	Percent
Arkansas	930	137	13.13	58
Colorado	2,300	45	3.52	36
Idaho	700	86	10.16	70
Illinois	1,400	110	14.22	59
Indiana	750	118	18.10	79
Kansas	10,800	60	7.49	27
Missouri	1,550	115	16.25	64
Michigan	1,900	58	4.69	30
Nebraska	2,100	62	5.20	25
Ohio	1,100	137	16.59	52
Oklahoma	5,000	73	6.42	21
Oregon	800	72	7.66	65
South Dakota	1,300	64	4.22	31
Texas	2,800	74	7.34	40
Washington	750	71	9.46	70
1991 average	34,180	74	8.65	36

1/ Preliminary. States listed harvested 86 percent of U.S. winter wheat acres in 1991. 2/ Based on data from those farmers who used purchased seed.

The band of States from Montana and South Dakota, south to Texas, tend to rely on their own farm production for seed.

U.S. Seed Exports and Imports

Corn Seed Exports

In 1990, total volume of U.S. field corn seed exports rose sharply to 70,366 metric tons, a jump of 91 percent from 1989, because of plentiful supplies following favorable weather conditions and strong foreign demand (table 13). Exports to all traditional trading partners, including unified Germany, increased sharply. Only Greece and Turkey showed declines in imported corn seed. Exports to unified Germany expanded due to political changes and development of new trade relations.

Table 13--U.S. corn seed exports by volume

Country	1988	1989	1990	Change 89-90	January-June 1990	January-June 1991	Change 90-91
	Metric tons			Percent	Metric tons		Percent
Canada	2,582	1,548	4,076	163	3,171	2,807	-11
Mexico	3,312	10,205	10,329	1	7,960	6,104	-23
France	2,453	2,873	9,666	236	1,997	3,840	92
Germany	62	522	1796	244	116	8,150	6926
Spain	4,134	1,836	4,132	125	2,893	1,332	-54
Italy	8,741	12,168	20,359	67	12,616	11,004	-13
Netherlands	1,061	351	2,437	594	264	1,973	647
Greece	2,251	1,999	1,828	-9	1,731	2,814	63
Romania	2,424	107	1,050	881	1,050	2,530	141
Union of Soviet Socialist Rp.	15	0	2,459	NA	2,459	3,569	45
Turkey	1,101	245	59	-75	59	171	190
Japan	1,322	1,051	1,431	36	473	630	33
Subtotal	29,458	32,905	59,622	81	34,789	44,924	29
Total	33,732	36,859	70,366	91	37,220	52,676	42

NA = Not applicable

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Total corn seed exports to the 12 leading countries rose 29 percent in the first 6 months of 1991 over the corresponding period of 1990. Overall exports were up 42 percent during this period. Exports to Canada, Mexico, Spain, and Italy, however, fell 11, 23, 54, and 13 percent in the first 6 months of 1991. Increased exports to France, Germany, Netherlands, Greece, Romania, and USSR more than offset these declines.

Corn Seed Imports

The volume of total corn seed imports in 1990 was 13,996 metric tons, a decline of 38 percent from 1989 as domestic seed stocks were replenished (table 14). In 1989, corn seed imports increased sharply to supplement 1988 drought-reduced domestic supply. However, corn seed imports accounted for a very small component (0.2 percent) of U.S. corn seed use in 1990.

Traditionally, Canada has been the largest supplier of seed corn to the United States while imports from Argentina, Chile, and Hungary have varied widely. Imports from Canada increased 3 percent in 1990. In the first 6 months of 1991, total U.S. corn seed import volume equaled 7,913 metric tons, a decline of 30 percent over the same period a year earlier.

Table 14--U.S. corn seed imports by volume

Country	1988	1989	1990	Change 89-90	January-June 1990	January-June 1991	Change 90-91
	Metric tons			Percent	Metric tons		Percent
Canada	3,935	7,753	8,010	3	5,356	3,940	-26
Argentina	0	2,457	511	-79	511	138	-73
Chile	2,055	7,000	4,509	-36	4,509	3,362	-25
Hungary	1,327	3,708	881	-76	881	0	-100
Subtotal	7,317	20,918	13,911	-33	11,257	7,440	-34
Total	7,909	22,672	13,996	-38	11,354	7,913	-30

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Soybean Seed Exports

The volume of 1990 soybean seed exports to France, Italy, Japan, and Canada rose 184, 177, 45, and 15 percent, respectively, as domestic seed supplies increased. These increases, however, were overshadowed by a 63 percent decline in exports to Mexico, resulting in a 19 percent decline in total U.S. soybean seed exports (table 15). Although U.S. exports to Mexico fell sharply in 1990 from the unprecedented level in 1989, they were well above the usual quantities. U.S. soybean seed exports to Mexico in 1989 were unusually high following the 1988 drought that drastically reduced supplies.

Sharp increases in exports to Japan, France, and Italy in the first 6 months of 1991 compared to the corresponding period of 1990, offset declines in exports to Mexico and Turkey. As a result, exports to the leading countries increased 6 per-

Table 15--U.S. soybean seed exports by volume

Country	1988	1989	1990	Change 89-90	January-June 1990	January-June 1991	Change 90-91
	Metric tons			Percent	Metric tons		Percent
Canada	293	390	449	15	444	425	-4
Mexico	8,922	100,380	36,731	-63	18,790	4,515	-76
France	2,187	1,698	4,827	184	2,689	3,948	47
Italy	27,833	20,185	55,937	177	40,422	56,757	40
Turkey	3,798	2,777	2,835	2	2,835	1,838	-35
Japan	5,277	1,608	2,325	45	1,697	3,480	105
Subtotal	48,310	127,038	103,104	-19	66,877	70,963	6
Total	53,730	128,582	106,991	-17	110,959	100,665	-9

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

cent in the first 6 months. However, overall soybean exports fell 9 percent.

Total Exports

The value of total seed exports rose 15 percent to $588 million in 1990 from a year earlier. This increase primarily reflects gains in corn, flower, vegetable, forage, and sugarbeet seed exports, which rose 103, 18, 15, 8, and 100 percent, respectively. These gains were partly offset by declines of 51, 50, and 17 percent in grain sorghum, tree and shrubs, and soybean seed exports, respectively (table 16).

Italy, Mexico, Canada, Japan, France, and Netherlands continued to be the top markets for U.S. planting seeds in calendar year 1990. However, 10 percent of total U.S. seed was exported to Saudi Arabia for the second year in a row. These countries together accounted for 71 percent of the total export value (table 17). Italy, with 17 percent of the total export value, held first position, followed by Mexico with 14 percent. These two countries switched positions in

Table 16--Exports and imports of U.S. seed for planting 1/

Item	1987	1988	1989	1990	Change 89-90
	$ million				Percent
Exports:					
Forage	75	94	96	104	8
Vegetable	138	167	153	176	15
Flower	9	9	11	13	18
Corn 2/	63	67	68	138	103
Grain sorghum	16	29	55	27	-51
Soybean	36	26	54	45	-17
Tree/shrub	2	3	4	2	-50
Sugarbeet	1	2	1	2	100
Other	33	27	68	81	19
Total	373	424	510	588	15
Imports:					
Forage	65	52	44	35	-20
Vegetable	49	58	56	60	7
Flower	21	21	24	23	-4
Corn 3/	5	10	37	18	-51
Tree/shrub	1	2	2	2	0
Other	4	4	6	7	17
Total	145	147	169	145	-14
Trade balance	228	277	341	443	30

1/ Totals may not add due to rounding. 2/ Not sweet, not food aid. 3/ Certified.

Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

Table 17--Export U.S. seeds for planting; region and country share, by value 1/

Region/country	1986	1987	1988	1989	1990
	Percent				
North and Central America:					
Canada	6.5	9.4	8.3	6.2	10.2
Mexico	12.8	13.0	12.6	25.4	14.4
Others	2.1	2.3	2.1	1.8	1.8
Total	21.4	24.7	23.0	33.4	26.3
South America:					
Brazil	1.2	1.2	1.2	0.6	0.5
Argentina	2.6	2.5	3.0	2.0	1.7
Colombia	1.1	0.9	1.1	0.6	0.5
Venezuela	3.1	1.4	3.3	0.6	0.4
Others	1.3	1.5	2.3	2.0	1.1
Total	9.3	7.6	10.8	5.9	4.3
Western Europe:					
United Kingdom	2.8	2.6	2.9	2.6	1.9
Netherlands	6.0	5.4	4.4	4.2	4.9
France	6.4	4.5	4.5	3.7	7.3
Germany	1.7	1.6	1.4	1.3	1.7
Spain	1.7	2.1	4.4	2.9	3.4
Italy	13.1	19.3	12.4	11.2	16.7
Greece	2.3	1.3	1.8	1.0	1.4
Others	3.5	2.8	3.1	2.5	3.1
Total	37.6	39.7	34.9	29.4	40.5
USSR & Eastern Europe:					
Hungary	0.6	0.1	0.4	0.3	0.6
Others	1.2	0.1	1.5	0.7	1.4
Total	1.8	0.2	2.0	1.0	2.0
Asia:					
Turkey	3.1	2.0	1.0	1.5	1.0
Iraq	2.3	1.8	2.3	1.2	0.4
Saudi Arabia	3.7	2.0	4.2	10.4	10.0
Japan	9.9	12.3	11.8	8.9	7.7
South Korea	0.9	1.0	1.0	0.7	0.6
Others	4.8	3.6	4.2	3.3	2.9
Total	24.7	22.6	24.4	26.0	22.6
Africa:					
South Africa	1.3	1.5	1.1	1.2	0.9
Egypt	0.6	0.8	0.8	0.8	0.4
Others	1.4	0.7	1.0	0.8	1.4
Total	3.3	3.0	2.9	2.7	2.7
Oceania:					
Australia	1.6	1.8	1.7	1.2	1.2
New Zealand	0.3	0.3	0.3	0.3	0.2
Others	0.0	0.1	0.0	0.0	0.1
Total	2.0	2.2	2.0	1.6	1.5
Total	100.0	100.0	100.0	100.0	100.0

1/ Totals may not add due to rounding.

1990. Third position was shared by Canada and Saudi Arabia with 10 percent of the export value.

On a regional basis, North and Central America, Western Europe, and Asia typically account for about 90 percent of the total value of seed exports.

Total Imports

Total seed imports reached $145 million in 1990, a decline of 14 percent from a year earlier. These declines are largely attributed to a fall of 51, 20, and 4 percent in corn, forage, and flower seed imports, respectively. The net U.S. seed trade balance surged 30 percent to $443 million in 1990 from a year earlier (table 16).

In calendar year 1990, Canada continued to be the leading U.S. supplier of planting seeds, with 26 percent of total seed import value (table 18). Chile with 11 percent, was the second largest source, followed by the Netherlands (9 percent). Mainland China supplied about 7 percent of 1990 total seed imports by value.

Table 18--Import U.S. seeds for planting; region and country share, by value 1/

Region, country	1986	1987	1988	1989	1990
			Percent		
North and Central America:					
Canada	35.2	37.7	30.4	27.0	26.1
Mexico	2.9	2.0	2.1	3.0	3.4
Guatemala	2.7	2.5	2.4	2.3	2.7
Costa Rica	2.6	2.1	0.7	0.9	1.3
Others	0.1	0.1	0.1	0.0	0.0
Total	43.4	44.4	35.8	33.2	33.4
South America:					
Chile	6.2	4.0	6.8	13.3	11.2
Argentina	0.0	1.5	0.7	4.0	1.0
Others	0.8	0.5	0.8	0.4	0.1
Total	7.0	6.0	8.3	17.7	12.3
Western Europe:					
Denmark	1.2	2.1	1.9	1.5	1.4
United Kingdom	0.6	0.8	0.6	0.5	0.8
Netherlands	10.5	10.2	9.2	8.9	9.3
France	1.1	1.7	1.0	1.3	1.4
Germany	2.2	2.5	2.2	1.8	1.6
Italy	1.1	1.2	1.6	1.0	1.0
Others	1.9	0.7	0.3	1.4	0.1
Total	18.7	19.2	16.8	16.3	15.7
USSR & Eastern Europe:					
Hungary	0.0	0.0	1.2	3.1	0.7
Others	0.4	0.5	0.1	0.1	0.1
Total	0.4	0.5	1.3	3.1	0.7
Asia:					
India	6.5	2.9	7.5	3.5	3.1
Thailand	0.0	0.7	1.6	2.8	5.4
Taiwan	6.0	6.7	4.5	6.3	4.8
Japan	6.1	6.0	6.4	6.9	7.6
China (Mainland)	0.0	0.0	2.4	4.0	6.8
Others	3.6	3.1	2.0	1.5	2.9
Total	22.2	19.4	24.5	25.0	30.5
Africa:					
Ethiopia	2.8	3.0	3.3	0.1	0.1
South Africa	0.5	0.1	0.5	0.0	0.0
Others	0.6	0.8	0.0	0.6	0.8
Total	4.0	3.9	3.8	0.7	0.9
Oceania:					
Australia	1.8	2.1	1.8	1.6	2.2
New Zealand	2.6	4.5	5.6	2.4	4.2
Total	4.3	6.5	7.4	4.0	6.4
Total	100.0	100.0	100.0	100.0	100.0

1/ Totals may not add due to rounding.

Fertilizer

Recent political and economic changes in Eastern Europe, USSR, and the Middle East will likely cut the increase in world fertilizer production and consumption. Ammonia plants in Kuwait and Iraq, damaged during the Gulf War, are not likely to be repaired in the near future, nor will new plant construction be completed as scheduled.

The most immediate impact of changes in Eastern Europe and USSR has been a sharp fall in fertilizer consumption. Fertilizer prices are no longer subsidized and Eastern European farmers are not willing to spend limited monies on fertilizers when relative prices of agricultural products are down sharply. The closure of non-economic plants and reduced investment in new plants could result from this reduced demand.

Fertilizer supplies in the United States during 1992 are expected to be ample at slightly higher prices. However, planted acreage of the major fertilizer-using crops will be the main factor determining 1992 usage and prices.

Consumption

U.S. plant nutrient use is estimated to have decreased to 20.1 million tons during the 1990/91 fertilizer year (July 1-June 30), down 3.0 percent from the 20.6 million tons a year earlier. Most of the decrease was due to less wheat planting. Corn acreage, which accounted for an estimated 44 percent of plant nutrient use in 1989/90, rose 2 percent; wheat acreage, 14 percent of nutrient use, decreased by 9 percent (table 19).

Table 19--Planted crop acreage, U.S.

Crop	1990	1991	Change
	Million acres		Percent
Wheat	77.3	70.0	-9
Feed grains	103.3	104.5	1
Corn	74.2	75.9	2
Other 1/	29.2	28.6	-2
Soybeans	57.8	59.8	3
Cotton	12.3	14.1	14
Rice	2.9	2.9	-1

1/ Sorghum, barley, and oats.

The April 1991 index of prices received by farmers for all fertilizers was 4 percent greater than spring 1990. Concern over the Middle East crisis, reduced world supplies, and increased oil prices resulted in higher fertilizer prices.

1991 Fertilizer Use on Winter Wheat

Fertilizer was applied to 84 percent of the winter wheat acres harvested in 1991 (table 20), about equal to the previous year. The proportion of winter wheat acres treated with nitrogen, phosphate, and potash remained about the same at 84, 49, and 19 percent, respectively. Nitrogen and phosphate per-acre application rates increased from 62 and 38 pounds to 65 and 40 pounds, respectively. The application rate for potash decreased 3 pounds to 54. Idaho acreage received the most nitrogen per acre at 100 pounds, while Illinois had the highest application rates for phosphate and potash at 65 and 83 pounds per acre, respectively. The least amount of nitrogen per acre (28 pounds) was applied in South Dakota.

1990 Fertilizer Use on Fall Potatoes

Some fertilizer was applied to 99 percent of the acreage planted to fall potatoes in 1990; the proportion of acres treated ranged from 98 percent for nitrogen to 89 percent for potash (table 21). The national average for nitrogen was 198 pounds per acre, while that for phosphate was 163 pounds, and 143 pounds for potash.

Application rates for the 3 nutrients varied significantly by State. Similar to last year, North Dakota acreage received the least amount of all fertilizer nutrients, while Oregon, Washington, and Wisconsin received the most.

Table 20--Fertilizer use on winter wheat, 1991 1/

State	Acres 2/	Fields in survey	Acres receiving: Any ferti-lizer-	Acres receiving: N	Acres receiving: P205	Acres receiving: K20	Application rates: N	Application rates: P205	Application rates: K20	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	Thousand	No.	Percent				Pounds per acre			Percent		
Arkansas	930	64	100	100	36	36	96	44 *	53	1	66	32
Colorado	2,300	86	54	54	22	2	48 *	31 **	2	83	9	9
Idaho	700	85	78	78	51	3	100	35	21 *	41	32	28
Illinois	1,400	76	96	96	94	83	87	65	83	15	4	81
Indiana	750	69	99	97	87	86	80	58	69	18	12	71
Kansas	10,800	358	89	89	49	8	57	32	26 *	69	8	22
Missouri	1,550	73	99	99	79	83	89	51	59	35	10	55
Montana	1,900	90	73	73	71	8	36	27	8 **	91	nr	9
Nebraska	2,100	96	80	80	30	4	42	29	11 **	80	10	11
Ohio	1,100	68	99	99	91	93	77	61	67	5	15	81
Oklahoma	5,000	149	92	92	45	7	67	35	26 *	52	15	33
Oregon	800	83	98	98	11	6	58	38 *	32 **	81	9	11
South Dakota	1,300	69	41	41	30	3	28 **	39 **	4 **	78	7	14
Texas	2,800	174	72	72	37	12	86	39	26 **	62	9	29
Washington	750	115	99	98	28	9	72	26 *	21 **	78	6	17
Area	34,180	1,655	84	84	49	19	65	40	54	58	12	30

= Insufficient data. nr = None reported. * = CV greater than 10 percent. ** = CV greater than 20 percent.

1/ Preliminary. 2/ Acres harvested for winter wheat.

Table 21--Fertilizer use on fall potatoes, 1990

State	Acres planted 1/	Fields in survey	Acres receiving: Any ferti-lizer-	Acres receiving: N	Acres receiving: P205	Acres receiving: K20	Application rates: N	Application rates: P205	Application rates: K20	Proportion fertilized: At or before seeding	Proportion fertilized: After seeding	Proportion fertilized: Both
	1,000	No.	Percent				Pounds per acre			Percent		
Colorado	66	56	100	100	100	95	219	189	80 *	13	0	88
Idaho	395	256	100	100	99	83	225	169	98	22	6	72
Maine	81	150	100	98	100	100	158	171	172	89	1	11
Michigan	34	60	100	100	100	98	162	150	216	28	0	72
Minnesota	69	114	95	93	91	88	100	84	156	78	0	22
New York	2/ 23	42	100	100	100	100	135	170	202	52	0	48
North Dakota	145	73	97	96	96	92	92	83	68 *	75	1	24
Oregon	53	82	99	99	98	73	246	218	175	25	0	75
Pennsylvania	23	65	100	100	94	97	147	141	131	69	0	31
Washington	129	174	100	100	97	97	294	239	224	41	16	43
Wisconsin	69	85	100	100	94	98	209	165	306	26	0	74
Area	1,087	1,157	99	98	98	89	198	163	143	41	4	54

* = CV greater than 10 percent.

1/ Preliminary. 2/ Does not include Long Island.

1990 Use of Manure, Lime, Sulfur, and Micronutrients

Manure was applied to 17 percent (15 percent in 1989) of all corn acres surveyed in 1990 (table 22). Use ranged from 43 percent (40 percent in 1989) of corn acres in Wisconsin to 4 percent in Missouri. Manure use on other crop acreage surveyed was less common, ranging from 6 percent for soybeans to less than 1 percent for rice. Micronutrient use also varied considerably by crop; over half of the potato acres planted received micronutrients in 1990, while only 2 percent of wheat acres were treated.

Lime is applied to balance a soil's pH (a measure of its acidity or alkalinity) which increases the yield potential of crops by improving the availability of soil nutrients. The frequency of lime applications can range from every year on highly acidic soils to every 5-10 years on the less acidic soils in the Midwest. Lime was applied to 6 percent of the corn acres surveyed in 1990, but no lime was used on durum wheat. Lime application rates ranged from 1.8 tons per acre for winter wheat to 0.9 tons for potatoes.

Like other essential nutrients, sulfur plays an important role in plant growth. Plants low in sulfur are often small and spindly, and sulfur deficiency can cause reduced root nodulation in legumes. Sulfur use was more common than lime on all crops surveyed except soybeans. Sulfur use was most prevalent on fall potatoes; calcium sulfate is frequently applied to extend potato storage life. Of potato acres surveyed,

Table 22--Manure, lime, sulfur, and micronutrient use on selected crops, 1990

Crop	Acres 1/	Acres receiving: Manure	Lime	Sulfur	Micro-nutrients	Application per acre: Lime	Sulfur
	1,000	Percent				Tons	Pounds
Corn	58,800	17	6	9	11	1.6	11
Cotton	9,730	4	2	23	17	1.0	10
Potatoes	1,087	5	7	48	50	0.9	57
Rice	1,800	*	1	13	14	1.0	11
Soybeans	48,250	6	4	[illegible]	[illegible]	1.4	15
Wheat:							
All	59,100	3	[illegible]	7	2	1.8	[illegible]
Durum	3,100	5	nr	nr	nr	nr	nr
Spring	15,800	6	*	2	2	nr	11
Winter	40,200	2	2	9	2	1.8	[illegible]

nr = None reported. * = Less than 0.5 percent.

1/ Includes the major producing States for each crop. Information is based on harvested acres for winter wheat and planted acres for all other crops.

48 percent received an average of 57 pounds of sulfur per acre in 1990.

Regulatory Action

The Environmental Protection Agency (EPA) decided not to regulate phosphoric acid production wastes under the Resource Conservation Recovery Act (RCRA). EPA determined that this would have been too costly and inflexible for the industry. Instead, EPA will regulate phosphoric acid waste water and phosphogypsum under the Toxic Substances Control Act (TSCA), which is more flexible than RCRA. EPA plans to work with the industry to implement the most promising alternatives as soon as possible.

Futures Market

The Chicago Board of Trade (CBOT) started diammonium phosphate (DAP) — 18-46-0 — futures on October 18, 1991. The contracts includes lots of 100 short tons for delivery in Central Florida in March, June, September, and December. CBOT hopes there will be interest from major foreign buyers such as India and China as well as U.S.-based companies. CBOT is also preparing an anhydrous ammonia futures contract; industry representatives recently received a preliminary draft.

Supplies

Effective January 1990, the U.S. Department of Commerce (DOC) reinstated the reporting of anhydrous ammonia quantity data for all countries except imports from the USSR. Imports from the USSR represent a large portion of U.S. imports. Thus, nitrogen imports and domestic supply are significantly understated in this report.

Domestic supplies of nitrogen, phosphate, and potash in 1990/91 increased from a year earlier. Supplies increased because of expanded domestic production and increased imports of nitrogen and potash materials (table 23).

Table 23--U.S. fertilizer supplies 1/

Item	1989/90	1990/91	Change
	Million short tons		Percent
July 1 inventory:			
Nitrogen	1.51	1.14	-25
Phosphate 2/	.70	.52	-26
Potash	.22	.34	55
Production:			
Nitrogen	13.45	13.89	3
Phosphate 2/	11.78	12.22	4
Potash	1.83	1.83	0
Imports:			
Nitrogen	3/ 2.43	3/ 3.42	41
Phosphate 2/	.07	.05	-29
Potash	4.16	4.61	11
Exports:			
Nitrogen	3/ 3.14	3/ 3.37	7
Phosphate 2/	5.49	5.57	2
Potash	.39	.63	62
Domestic supply: 4/			
Nitrogen	3/ 14.25	3/ 15.08	6
Phosphate 2/	7.06	7.22	2
Potash	5.82	6.15	6

1/ Data for July through June for the fertilizer year starting July 1. 2/ Does not include phosphate rock. 3/ Does not include imports of anhydrous ammonia from the USSR. Thus, nitrogen imports and domestic supply are significantly understated. Also, aqua ammonia imports include only calendar year 1989 and January-June 1990 data. 4/ Includes requirements for industrial uses.

Trade

U.S. phosphate exports (nutrient content) during July 1990-June 1991 increased 1 percent. Potash exports were up by 63 percent from a year earlier. Exports to Brazil and Japan increased 142 and 65 percent, respectively, and China and Venezuela received shipments (none during the previous year) during the fertilizer year. The increase in potash exports follows a 3 percent drop from 1988/89 to 1989/90.

The volume of fertilizer materials exported from the United States varied when compared with year-earlier levels. For July 1990-June 1991, DAP exports climbed 6 percent from 9.0 to 9.5 million tons while monoammonium phosphate exports decreased 18 percent from 917,000 to 749,000 tons. Phosphate rock exports continued to decline to 6.6 million tons, a 21 percent decrease.

Nitrogen solution exports increased 4 percent from 429,000 tons in 1989/90 to 447,00 in 1990/91. Urea exports decreased 16 percent from 1.2 to 1.0 million tons, and concentrated superphosphate exports increased 3 percent from 731,000 to 752,000 tons. Exports of ammonium nitrate decreased 83 percent, while ammonium sulfate, potassium chloride, and potassium sulfate increased 7, 90, and 14 percent, respectively.

The main fertilizer deficit areas will continue to be in Asia, particularly China and India. In addition, France, Belgium,

Italy, Japan, Pakistan, Korea, Mexico, and Brazil continue to be major recipients of U.S. fertilizer. During July 1990-June 1991, over 46 percent of urea exports and 45 percent of diammonium phosphate exports — representing 488,000 and 4.3 million tons of product, respectively — went to China. Fertilizer consumption in China has grown rapidly during the past few years, making it the world's third largest consumer of manufactured fertilizer nutrients after the USSR and the U.S. Export needs there will increase steadily because of the delayed increase in domestic production, but prices are expected to be higher unless subsidized by the government. India and Chile received another 15 percent of DAP and urea exports, respectively.

Belgium-Luxembourg and France remain important buyers of U.S. nitrogen solutions, receiving 190,000 and 194,000 tons (86 percent) of these exports during 1990/91. Brazil and El Salvador received 399,000 and 143,00 tons or 40 and 14 percent of ammonium sulfate exports, respectively. Brazil also received 306,000 tons or 38 percent of potassium muriate exports. Bangladesh and Chile received 184,000 and 133,000 tons or 25 and 18 percent of concentrated superphosphate exports. Phosphate rock exports have declined as a result of increased còmpetition from Morocco. However, Mexico, South Korea, Canada, Japan, the Netherlands, France, and India remained the major recipients.

Fertilizer material imports for many products were greater than year-earlier levels. Urea imports increased 2 percent from 1.9 to 2.0 million tons with Canada responsible for exporting 46 percent of the total. Potassium chloride imports during July-June were up 11 percent from a year earlier to 7.5 million tons. Imports of potassium chloride from Canada remained strong at around 93 percent of the total, and those from Israel decreased to 3 percent at 255,000 tons. However, ammonium nitrate imports were down 8 percent from 443,000 to 408,000 tons, and ammonium sulfate imports dropped 25 percent to 317,000 tons. Anhydrous ammonia imports for January-June 1991 were down 4 percent.

Production

Domestic nitrogen and phosphate fertilizer production increased during 1989/90 in response to higher domestic prices and more than anticipated use, while potash production remained about the same. Nitrogen production increased 3 percent during July 1990-June 1991 because some anhydrous ammonia producers have operated at close to capacity since the Middle East crisis caused tighter world supplies. Phosphate production increased 4 percent in response to greater product demand and prices. Potash production remained near year earlier levels since world supply-demand situation was close to balance.

Prices

Aggregate farm fertilizer prices in spring 1991 were 4 percent more than a year earlier (table 24). Spring 1991 fertilizer prices rose 2 percent from October 1990, following a 2 percent increase from April 1990. Concerns over the world demand-supply situation, as a direct result of the Middle East crisis, pushed prices up. The increase in 1991 planted acres anticipated by the fertilizer industry did not materialize as expected, resulting in only modest increases in fertilizer prices between fall 1990 and spring 1991.

Nitrogen prices showed the greatest gain since spring 1990, with urea and anhydrous ammonia prices climbing 15 and 5 percent, respectively. The Middle East crisis impacted anhydrous ammonia and urea prices more than other fertilizers. Prices of other nitrogen materials either remained constant or slightly increased. Triple superphosphate and diammonium phosphate prices went up 8 percent each. Potash prices also increased slightly; the price of potassium chloride reached $156 per ton in April.

Prices paid by farmers for fertilizer products reflect wholesale trends as well as other economic relationships. Since spring 1991, fertilizer wholesale prices have dropped in response to excess domestic supplies and reduced demand. This seasonal down-turn in prices will likely reverse direction later this fall as dealers increase stocks in anticipation of demand next year. Fall retail prices will likely be equal to or slightly less than spring 1991 prices. Spring 1992 prices will be higher than fall 1991 prices and will reflect expectations for 1992 planted acreage and fertilizer production costs.

Table 24--April farm fertilizer prices 1/

Year	Anhydrous ammonia (82%)	Triple super-phosphate (44-46%)	Diammonium phosphate (DAP) (18-46-0%)	Potash (60%)	Mixed (6-24-24%)	Prices paid index 1977=100
	Dollars per short ton					
1987	187	194	220	115	176	117
1988	208	222	251	157	208	132
1989	224	229	256	163	217	141
1990	199	201	219	155	198	130
1991	210	217	[illegible]	156	206	135

1/ Derived from the April survey of farm supply dealers conducted by NASS, USDA.

Pesticides

Prices

Herbicide and insecticide prices have generally risen over the past 3 years (table 25). Pesticide manufacturers increased expenditures for research and development of new products and to develop additional data to reregister older

Table 25--April farm pesticide prices 1/

Pesticides	1989	1990	1991	Change 90-91
	Dollars per pound 2/			Percent
Herbicides:				
Alachlor	5.40	5.70	6.15	7.9
Atrazine	2.70	2.93	3.25	10.9
Butylate	3.10	3.13	3.34	6.7
Cyanazine	5.03	5.43	5.65	4.1
Metolachlor	6.61	6.94	7.49	7.9
Trifluralin	6.60	6.70	7.50	11.9
2,4-D	2.61	2.71	2.83	4.4
Composite 3/	4.43	4.64	5.04	8.6
Insecticides:				
Carbaryl	4.08	4.36	4.44	1.8
Carbofuran	9.51	9.77	10.39	6.3
Chlorpyrifos	9.05	9.65	10.65	10.4
Fonofos	8.96	9.52 6/	10.30	8.2
Methyl parathion 4/	3.85	2.94	4.15	41.2
Phorate	6.85	7.25	7.78	7.3
Pyrethroids 5/	48.08 6/	50.00	56.54	13.1
Terbufos	10.13	10.52	11.28	7.2
Composite 3/	10.67	10.91	12.33	13.0

1/ Derived from the April survey of farm supply dealers conducted by NASS, USDA. 2/ Active ingredients. 3/ Includes above materials and other major materials but not products registered in the last 2 to 3 years. 4/ Supplied by Fred Cooke, Mississippi Agricultural Experiment Station. 5/ Average of fenvalerate and permethrin prices based on 2.6 pounds active ingredient per gallon. 6/ Revised.

products. In addition, many pesticide manufacturers have embarked on expensive biotechnology research. Dealer costs also have risen, especially for liability insurance.

Average farm-level herbicide prices rose 8.6 percent between 1990 and 1991, after a 4.7 percent hike a year earlier. Trifluralin, a major soybean and cotton herbicide, showed the greatest increase — 11.9 percent. Atrazine, a major corn and grain sorghum herbicide, was second at 10.9 percent.

Farm-level insecticide prices jumped 13.0 percent, compared with 2.2 percent last year. The price of methyl parathion (used extensively in cotton production for boll weevil control) was up a whopping 41 percent in 1991, following a decrease of 24 percent a year earlier. The mild winter of 1990-91 indicated an upsurge in boll weevil pressure. Growers therefore stocked up on methyl parathion; tightening supplies and increasing the price.

Consumption

Total 1991 farm pesticide use on major field crops is projected at 478 million pounds active ingredients (a.i.), up 15 million from 1990 (table 26). June planted acreage for the 10 major field crops declined from 256 million in 1990 to 253 million in 1991. The area planted to row crops, which tend to be pesticide intensive, increased, while that for small grains decreased. Corn and soybeans accounted for 82 percent of herbicide consumption, corn and cotton 73 percent of insecticide consumption, and peanuts 82 percent of fungicide consumption in 1990.

Table 26--Projected pesticide use on major U.S. field crops, 1991

Crops	June 1 planted acres	Herbicides	Insecticides	Fungicides
	Million	Million pounds (a.i.)		
Row:				
Corn	74.9	226	27.9	0.06
Cotton	13.9	21	20.5	0.22
Grain sorghum	11.0	11	1.7	0.00
Peanuts	2.0	7	1.6	7.25
Soybeans	59.8	106	9.2	0.06
Tobacco	0.8	1	2.9	0.38
Total	162.4	372	63.8	7.97
Small grains:				
Barley and oats	17.6	4	0.1	0.00
Rice	2.9	12	0.5	0.07
Wheat	70.0	15	2.0	0.81
Total	90.5	31	2.6	0.88
1991 total	252.9	403	66.4	8.85
1990 total	256.0	392	62.9	8.34

Pesticide Use on Fall Potatoes

Fall potatoes are grown across the northern United States, from Maine to Washington. Herbicides were applied to 81 percent of the fall potato acreage in the 11 surveyed States (table 27). However, in Minnesota and North Dakota, where rainfall is low, only 40 to 50 percent of the acreage is treated with herbicides. Insecticide use was fairly uniform across all States (table 28). The proportion of acreage treated with fungicides was highest in the humid eastern States and lowest in the more arid western States (table 29).

Herbicides were applied once on 59 percent of the fall potato acreage, and twice on 20 percent. Insecticide treatments averaged 2.1, ranging from 1.2-1.3 in Colorado and Idaho to 4.5 in Pennsylvania. Fungicide treatments were highest in Maine at 8.9, followed by Pennsylvania and Wisconsin at 4.9. In the Pacific Northwest, average fungicide treatments ranged from 1.4 to 1.7.

Herbicides

Metribuzin was the most commonly used herbicide in fall potato production (table 27). It was either used alone or in combination with other herbicides to broaden the weed control spectrum. Metribuzin requires moisture, shortly after treatment, to be effective. A large share of the fall potatoes in the Pacific Northwest are treated with metribuzin because most of the crop is irrigated. Metribuzin, generally applied after planting but before potatoes emerge, controls such weeds as foxtail, ragweed, pigweed, and mustard.

EPTC was the second most commonly used herbicide. It is a selective herbicide that can be applied preplant or after planting prior to weed germination. It controls pigweed, foxtail, and wild oats. EPTC must be incorporated into the soil because it is readily lost by volatization. It is most effective where rainfall is low, and is more often used in arid areas.

Table 27--Selected herbicides used in fall potato production, 1990 1/

Item	CO	ID	ME	MI	MN	NY 2/	ND	OR	PA	WA	WI	Area
1,000 acres planted	66	395	81	34	69	23	145	53	23	129	69	1087
1,000 acres treated with herbicides	50	369	79	31	37	21	54	43	19	119	63	885
Percent of planted acres treated:	76	93	98	91	54	91	37	81	83	92	91	81
With 1 treatment	22	67	94	49	40	56	34	49	54	72	60	59
With 2 treatments	54	21	3	39	14	26	3	22	22	18	29	20
With 3 treatments	nr	4	1	3	nr	7	nr	10	5	2	2	2
With 4 treatments	nr	1	nr	nr	nr	2	nr	nr	2	nr	nr	*
Average times applied	1.71	1.33	1.04	1.54	1.18	1.51	1.07	1.53	1.43	1.24	1.35	1.32
1,000 acre-treatments 3/	85	492	82	47	44	32	58	65	27	148	85	1164
Acre-treatments by active ingredient: 4/												
Single materials--												
EPTC	40	19	1	6	16	2	7	24	6	23	nr	17
Glyphosate	nr	*	nr	8	3	10	3	2	9	1	2	1
Linuron	4	*	27	16	2	14	nr	nr	10	nr	17	5
Metolachlor	3	1	nr	11	2	15	3	2	12	nr	2	2
Metribuzin	43	47	64	37	12	29	7	33	21	45	40	42
Pendimethalin	3	3	nr	nr	23	7	28	6	nr	5	9	6
Sethoxydin	nr	1	3	2	10	3	nr	1	nr	nr	[illegible]	2
Trifluralin	nr	2	nr	nr	19	nr	28	4	nr	4	nr	4
Other	3	*	nr	nr	nr	nr	nr	1	nr	2	nr	1
Combination mixes--												
Metolachlor + linuron	nr	nr	nr	8	nr	12	nr	nr	5	nr	nr	1
Metribuzin + EPTC	1	12	1	nr	nr	nr	10	12	nr	4	nr	7
Metribuzin + metolachlor	3	1	1	6	12	3	7	nr	34	nr	15	4
Metribuzin + pendimethalin	nr	6	nr	nr	nr	nr	7	7	nr	[illegible]	5	5
Trifluralin + EPTC	nr	2	nr	nr	nr	nr	nr	5	nr	1	nr	1
Other	nr	6	3	5	2	5	nr	3	3	10	3	5
Total	100	100	100	100	100	100	100	100	100	100	100	100

nr = None reported. * = Less than 1 percent.

1/ Preliminary. 2/ Excludes Long Island. 3/ Acres treated x times applied. 4/ Spot treatments not included.

Table 28--Selected insecticides used in fall potato production, 1990 1/

Item	CO	ID	ME	MI	MN	NY 2/	ND	OR	PA	WA	WI	Area
1,000 acres planted	66	395	81	34	69	23	145	53	23	129	69	1087
1,000 acres treated with insecticides	44	319	80	31	66	23	135	49	23	123	68	961
Percent of planted acres treated:	67	81	99	91	96	100	93	92	98	95	99	88
With 1 treatment	58	60	13	17	27	33	22	20	14	27	33	38
With 2 treatments	4	18	30	15	44	19	44	26	9	27	45	26
With 3 treatments	5	3	22	17	23	29	18	35	17	22	14	14
With 4 treatments	nr	nr	15	24	2	10	8	11	20	14	4	6
With 5 treatments	nr	nr	9	2	nr	2	1	nr	12	3	2	2
With 6 or more	nr	nr	10	16	nr	7	nr	nr	28	2	1	2
Average times applied 3/	1.22	1.31	3.18	3.36	1.99	2.50	2.18	2.42	4.45	2.41	2.00	2.05
1,000 acre-treatments	53	419	254	105	132	58	294	119	101	297	136	1966
Acre-treatments by active ingredient: 4/ 5/												
Single materials--												
Aldicarb	nr	2	nr	1	nr	nr	nr	2	2	2	nr	1
Azinphos-methyl	nr	*	17	8	nr	7	nr	nr	4	1	nr	3
Carbofuran	nr	2	1	4	30	2	38	2	3	1	1	9
Disulfoton	nr	3	5	3	nr	3	1	11	*	18	7	6
Endosulfan	7	1	15	11	2	5	2	nr	3	1	18	5
Esfenvalerate	67	14	13	7	22	15	9	1	6	1	17	12
Ethoprop	nr	24	1	2	nr	nr	nr	6	nr	7	nr	7
Fenvalerate	nr	*	nr	nr	nr	2	nr	nr	2	nr	10	1
Methamidophos	13	2	27	12	4	10	nr	23	7	32	4	12
Permethrin	4	7	8	1	nr	10	nr	9	16	5	19	6
Phorate	nr	39	1	12	14	1	18	14	12	10	11	16
Phosphamidon	nr	0	nr	nr	22	nr	26	nr	nr	3	nr	6
Other	4	5	4	24	5	30	6	30	24	15	13	11
All combination mixes	4	1	8	16	1	16	nr	2	22	7	1	5
Total	100	100	100	100	100	100	100	100	100	100	100	100

* = Less than 1 percent. nr = None reported.

1/ Preliminary. 2/ Excludes Long Island. 3/ Acres treated x times applied. 4/ Spot treatments not included.
5/ Data were not tabulated to reveal insecticide-fungicide combination mixes.

Insecticides

Colorado potato beetles, aphids, and leafhoppers constitute the major insect problems in potato production. The Colorado potato beetle has developed some resistance to a number of organophosphorus insecticides, and to some of the newer synthetic pyrethroids.

The most commonly used insecticides across all States are esfenvalerate, methamidophos, and phorate (table 28). Carbofuran and phosphamidon are used extensively in Minnesota and North Dakota. Carbofuran, a systemic, is generally applied at planting for flea beetle and early-season Colorado potato beetle control. Phosphamidon, an organophosphate, is still effective against the Colorado potato beetle and is inexpensive to use.

Fungicides

Mancozeb, maneb, and chlorothalonil are the most commonly used fungicides in fall potato production (table 29). Early and late blight are the two most serious diseases.

Early blight kills the potato vine, reducing the food supply available for tuber production in the hill. Late blight kills the vine, and can also infect developed tubers, making them vulnerable to decay in storage.

The disease organism is harbored in volunteer potato plants and in decaying vines and tubers left in the field. The disease organism contaminates the potato plant when rain splashes infected soil particles onto the foliage.

Mancozeb, maneb, and chlorothalonil are protective fungicides in that they must kill the disease organism before it invades the foliage. This explains the large number of fungicide treatments in high rainfall areas.

Herbicides on Winter Wheat

In 1991, herbicides were used on 27 percent of the winter wheat acreage in the surveyed States in 1991 (table 30). In Washington 92 percent of winter wheat acreage was treated, followed by Oregon and Montana at 76 and 73 percent. In the Corn Belt, the proportion treated ranged from 4 to 10 percent. In Washington and Oregon, winter annual broadleaf and grass weeds must be controlled during mild portions of the winter. In Montana, winterkill thins wheat stand and invading weeds must be controlled to prevent additional yield losses.

Chlorsulfuron and 2,4-D were the two most commonly used herbicides. Chlorsulfuron, registered in 1982, controls broadleaf and grass weeds and can be applied either pre- or postemergence. In contrast, 2,4-D controls only broadleaf

Table 29--Selected fungicides used in fall potato production, 1990 1/

Item	CO	ID	ME	MI	MN	NY 2/	ND	OR	PA	WA	WI	Area
1,000 acres planted	66	395	81	34	69	23	145	53	23	129	69	1087
1,000 acres treated with fungicides	65	155	80	29	60	22	113	41	22	95	67	749
Percent of planted acres treated:	98	39	99	85	87	96	78	77	96	74	97	69
With 1 treatment	34	25	nr	26	42	14	37	44	6	56	11	29
With 2 treatments	46	12	1	26	16	21	32	24	11	11	19	18
With 3 treatments	14	1	2	12	8	14	4	4	19	5	9	5
With 4 treatments		nr	1	3	2	33	4	4	16	2	7	3
With 5 treatments	nr	nr	7	5	4	5	nr	1	8	nr	5	2
With 6 treatments	nr	nr	5	7	7	7	1	1	9	nr	11	2
With 7 treatments	nr	nr	11	nr	4	2	nr	nr	12	nr	9	2
With 8 treatments	nr	nr	17	nr	4	nr	nr	nr	8	nr	15	3
With 9 treatments	nr	nr	12	3	nr	nr	nr	nr	2	nr	11	2
With 10 or more	nr	nr	43	3	nr	nr	nr	nr	7	nr	nr	3
Average times applied	1.91	1.41	8.86	3.04	2.48	3.24	1.75	1.73	4.90	1.36	4.89	2.93
1,000 acre-treatments 3/	124	219	708	90	150	73	199	71	108	129	330	2199
Acre-treatments by active ingredient: 4/ 5/												
Single materials--												
Chlorothalonil	45	54	16	4	13	6	nr	18	8	7	10	17
Iprodione	1	2	nr	nr	nr	nr	nr	19	nr	41	nr	3
Mancozeb	1	17	38	57	57	20	32	9	62	11	62	37
Maneb 6/	5	13	35	15	15	17	39	4	*	9	10	21
Metiram	nr	nr	nr	4	nr	21	nr	nr	nr	3	nr	1
Triphenyltin hydroxide	31	1	nr	1	7	1	16	nr	nr	1	7	5
Other	17	11	1	6	nr	nr	nr	37	nr	18	5	6
Combination mixes--												
Mancozeb + metalaxyl	nr	*	5	4	1	14	nr	9	18	6	2	4
Other	nr	1	5	9	7	21	13	4	13	3	5	6
Total	100	100	100	100	100	100	100	100	100	100	100	100

* = Less than 1 percent. nr = None reported.

1/ Preliminary. 2/ Excludes Long Island. 3/ Acres treated x times applied. 4/ Spot treatments not included. 5/ Data were not tabulated to reveal insecticide-fungicide combination mixes. 6/ Includes maneb + zinc.

Table 30--Selected herbicides used in winter wheat production, 1991 1/

Item	AR	CO	ID	IL	IN	KS	MO	MT	NE	OH	OK	OR	SD	TX	WA	Area
1,000 acres harvested	930	2300	700	1400	750	10800	1550	1900	2100	1100	5000	800	1300	2800	750	34180
1,000 acres treated with herbicides	147	509	407	114	78	2167	69	1393	789	102	1156	612	495	595	689	9321
Percent of harvested acres treated:	16	22	58	8	10	20	4	73	38	9	23	76	38	21	92	27
With 1 treatment	16	15	52	8	10	19	4	70	36	9	22	66	35	20	77	25
With 2 or more	0	7	6	0	*	1	0	3	2	0	1	10	3	1	15	2
Average times applied	1.00	1.32	1.08	1.00	1.01	1.06	1.00	1.07	1.06	1.00	1.03	1.15	1.13	1.06	1.17	1.09
1,000 acre-treatments 2/	147	673	439	114	78	2293	69	1492	835	102	1186	701	561	629	806	10125
Acre-treatments by active ingredient: 3/								Percent								
Single materials--																
2,4-D	18	13	21	17	26	16	33	17	43	67	12	7	[illegible]	26	16	18
Chlorsulfuron	nr	nr	nr	nr	nr	54	nr	3	nr	nr	80	2	nr	14	1	23
Dicamba	nr	nr	1	nr	nr	4	nr	nr	8	nr	nr	13	nr	10	1	3
MCPA	nr	4	1	nr	13	1	nr	nr	3	33	nr	3	4	29	2	4
Metsulfuron	nr	11	nr	nr	nr	3	nr	1	[illegible]	nr	2	nr	29	6	nr	5
Other	nr	20	9	nr	nr	3	nr	9	nr	nr	nr	19	4	5	15	7
Combination mixes--																
2,4-D + chlorsulfuron	nr	nr	nr	nr	nr	8	nr	nr	nr	nr	5	nr	nr	nr	1	2
2,4-D + dicamba	nr	11	10	nr	nr	3	nr	16	5	nr	nr	6	nr	nr	1	5
2,4-D + glyphosate	nr	nr	2	nr	nr	nr	nr	3	nr	nr	nr	2	11	3	nr	1
2,4-D + metsulfuron	nr	24	nr	nr	nr	3	nr	29	33	nr	nr	nr	37	7	nr	12
Thifensulfuron + tribenuron	73	4	6	83	62	nr	67	nr	nr	nr	nr	2	nr	nr	5	4
Other 2-way mixes	nr	11	20	nr	nr	6	nr	21	nr	nr	nr	20	8	nr	12	9
3-way mixes	9	nr	29	nr	nr	nr	nr	1	nr	nr	nr	27	nr	nr	46	7
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

nr = None reported.

1/ Preliminary. 2/ Acres treated x times applied. 3/ Spot treatments not included.

weeds and is applied postemergence. Chlorsulfuron gained rapidly in popularity and by 1988 accounted for 49 percent of the winter wheat herbicide acre-treatments but by 1991 dropped to 23 percent. The reason is that weeds resistant to chlorsulfuron have been identified (kochia and Russian thistle) and farmers have been urged to rotate chlorsulfuron with other herbicides to slow resistance in other weed species.

Regulatory Issues

In October 1990, the Environmental Protection Agency (EPA) proposed canceling all granular formulations of carbofuran (a soil insecticide and nematicide), because of their association with bird mortality. EPA and the manufacturer have recently reached an agreement to severely restrict the sales of granular carbofuran and phase out many registered uses. Sales of granular carbofuran from September 1, 1991, through 1994 are limited to 4.5 million pounds a.i. with no more than 400,000 pounds a.i. sold in 1994.

For the 1993 growing season, all registered uses will be canceled except corn, sorghum (in Texas, Kansas, and Nebraska), rice, spinach grown for seed, cucurbits, cranberries, bananas, and pine progeny. Corn and sorghum uses will be dropped after September 1, 1993. Rice use will be dropped after September 1, 1994. The agreement allows the manufacturer to present new information to EPA concerning benefits or risks on corn, sorghum, or rice before the cancellation dates. If the new evidence is persuasive, EPA could allow continued usage on corn, sorghum, and/or rice. Beginning in 1995, no more than 2500 pounds a.i. of granular carbofuran formulations can be sold for the remaining uses: spinach grown for seed, cucurbits, cranberries, bananas grown in Hawaii, and pine progeny.

EPA also recently reached an agreement with the manufacturer of ethyl parathion to voluntarily cancel all registered uses as of December 31, 1991, except for alfalfa, barley, corn, cotton, sorghum, soybeans, sunflowers, and wheat. Use on canola might be available, if a residue tolerance is set. EPA has the option to review and cancel the remaining registered uses. Under the agreement, only aerial application by certified applicators is allowed, and crops treated with ethyl parathion have to be harvested mechanically. There are also application restrictions, including requirements for setbacks, reentry, wind speed, and protective clothing.

A final regulatory decision on EBDC fungicides (maneb, metiram, and mancozeb) is likely in late 1991 or early 1992. EBDC fungicides used on a wide variety of fruit, nut, vegetable, and grain crops are suspected of causing birth defects and tumors. In December 1989, EPA proposed canceling 45 of 55 registered uses. Earlier that year, four major registrants withdrew 42 of the 45 uses from their product labels.

Another issue concerning pesticides is the "circle of poison." The circle of poison refers to the potential linkage between domestic production and export of certain pesticides and the subsequent import of food products contaminated with those pesticides. Of particular concern are pesticides that are

neither registered in the United States nor available to U.S. farmers but, are legally manufactured and exported by U.S. companies. These pesticides can be used on food crops in foreign countries and exported for U.S. consumption. The circle is complete when pesticide residues appear on food consumed in the U.S.

The most controversial aspect of legislative proposals to sever the circle of poison is banning exports of unregistered pesticides manufactured in the United States. The Circle of Poison Prevention Act, introduced in Congress in late April, would ban the export of all pesticides which are not registered domestically or do not have food tolerances.

Substitutability of Crop Rotations for Agrichemicals: Preliminary Results

by

Biing-Hwan Lin, LeRoy Hansen, Stan Daberkow, and Michael Dreitzer[1]

Abstract: Production practices among corn farmers in the 10 major producing States were analyzed to delineate agrichemical use patterns among different cropping systems. Per acre insecticide use for continuous corn averaged 0.81 pounds of active ingredients, compared with 0.14 pounds for the corn-soybean system, suggesting the potential for reduced insecticide use through crop rotation. Furthermore, by rotating soybeans with corn, increased land productivity could potentially reduce nitrogen applications, according to a preliminary econometric analysis of corn input-output relationships.

Keywords: Crop rotation, farm chemical use, input substitutability

In recent years, health and environmental concerns have encouraged public policymakers and the private sector to examine ways to systematically reduce the quantity of chemicals used in agricultural production. Within the agricultural community, low-input, or sustainable agriculture, is an example of a concept embracing less chemically-intensive production regimes. Some studies have shown that low input techniques may produce an economic profit equivalent to conventional practices (2,3,7). However, to date there has been little change in per acre pesticide and fertilizer use on major field crops.

Crop rotations can provide economic and environmental benefits to agricultural producers and the general public. For example, legume-grain rotations are reported to often generate 10 to 20 percent higher grain yields than continuous grain, ceteris paribus (7, p.138). Increased land productivity (higher soil moisture and nutrient availability) and especially reduced pest pressure are some of the benefits from crop rotation (1). Such findings have led to recent government policies, including several provisions of the 1990 farm bill, that encourage crop rotation as a means of reducing the reliance on chemicals in agricultural production.

The objective of this study is to estimate the substitutability of crop rotations for agrichemicals (nitrogen, insecticides, and herbicides). To achieve this objective, agrichemical use patterns across different crop rotations are compared statistically using the 1990 corn Cropping Practices Survey. Additionally, an econometric analysis of corn input-output relationships is conducted. The econometric analysis and agrichemical use patterns among different crop rotations are used to examine the substitutability of crop rotations for agrichemicals.

Recent Policies Concerning Rotation and Chemical Use

The 1990 farm bill and companion legislation contain a number of provisions to encourage crop rotation. These actions represent an effort to promote the diversification of cropping patterns and decrease reliance on agrichemicals.

The Integrated Farm Management Program Option under the farm bill's Conservation Title attempts to provide significant planting flexibility in the base acreage in order to obtain environmental benefits. The Agricultural Water Quality Incentives Program also provides producers favorable terms for tailoring production practices, including crop rotations, towards reducing risks of ground and surface water contamination. In addition, the farm bill's Research Title discusses the potential for reducing harmful environmental effects of agricultural production practices through properly implemented alternative agricultural production techniques, which can include crop rotation.

Another policy that may encourage cropping diversity is the Omnibus Budget Reconciliation Act of 1990. The act's flexibility provision allows each producer planting flexibility on up to 25 percent of base acreage, without a program penalty. However, producers do not receive deficiency payment on these flexible acres. This provision allows producers to respond to market rather than program signals in their planting decisions. In doing so, some monoculture cropping bias may be reduced for program crops, especially for those producers whose ratio of base acreage to total cropland is large.

[1]Lin, Hansen, and Daberkow are agricultural economists, and Dreitzer was formerly a summer intern, Resources and Technology Division, Economic Research Service, USDA.

Data

Corn yields are hypothesized to be affected by soil and land characteristics, weather, and production practices. Information on soil characteristics is obtained from the 1985 National Resource Inventory and the associated Soils-5 survey. County averages are used to represent soil characteristics of each observation included in this study. Soil characteristics available in the National Resource Inventory are hypothesized to affect corn yields include: water holding capacity, permeability, slope length, soil erodibility factor (TFACT), and soil loss tolerance factor (KFACT). Water holding capacity, permeability, slope length, and TFACT are expected to positively affect corn yields. The effect of KFACT on yields can be positive or negative.

Weather data are from the National Oceanic and Atmospheric Administration (NOAA). Monthly averages of precipitation and temperature are available by NOAA multi-county weather district. Precipitation and temperature during July-August are believed to positively affect corn yields. However, too much precipitation and extremely high temperature can reduce corn yields.

Field-level data on production practices and the subsequent yields come from the USDA's 1990 Cropping Practices Survey, which is part of the Objective Yield Survey. The survey randomly samples fields in corn production for the major producing states. The following field-level production practices, all of which can potentially influence yields, were recorded in 1990.

Seed: Types of seed planted; seeding rate; seed cost; chemical treatment of seed.

Fertilizer: Whether manure was applied; whether soil was tested; the timing, quantity, frequency, and methods of nitrogen, phosphorus, and potash applications; use of a nitrogen inhibitor; use of lime, sulphur, and micro nutrients.

Pesticides: Frequency of weed cultivation; the timing, quantity, frequency, type, and method of herbicide and insecticide applications.

Tillage and Planting Operations: Tillage and planting implements used and the number of tillage passes between harvest of the previous crop and corn seeding; planting and harvesting dates.

Others: Whether the land is highly erodible; irrigated or not; the purpose of the crop (i.e., seed or grain production); farm program participation; crops planted during the last 2 years.

The three sets of data (Cropping Practices Survey, National Resource Inventory, and NOAA weather) are linked through county identifiers. Because a crop rotation may take more than three years to complete, the crops planted in three consecutive years as recorded in the Cropping Practices Survey represent a cropping sequence rather than rotation. However, in this article the term cropping pattern is used interchangeably with crop rotation.

Agrichemical Use Patterns in Corn Production

The 1990 Cropping Practices Survey data set included 1,465 usable observations sampled in the 10 major corn producing States (Michigan, Minnesota, Wisconsin, Illinois, Indiana, Iowa, Missouri, Ohio, Nebraska, and South Dakota). Those observations with reported corn yields of less than 30 or greater than 300 bushels per acre were excluded to focus the analysis on corn produced for feed and to avoid observations with extremely low yields (e.g., crop failure).

Crops planted in the previous 2 years (1988 and 1989) were recorded for each observation. Based on the reported previous crops, four major cropping patterns were identified and their associated agrichemical use patterns are summarized in table 1. The corn-soybean system (i.e., corn in 1990 and soybeans in 1989) was most common, accounting for 49 percent of the sample.

Monoculture corn, as indicated by 3 consecutive years of corn, was practiced on more than one-fifth of the sampled acres. Two consecutive years of corn (1989 and 1990) with a crop other than corn being planted in 1988 was also common. Previous crops other than corn and soybeans included alfalfa and small grains. Also, a sizable number of acres were left fallow in 1989. (See the special article by Gill and Daberkow in this issue for more detail).

Insecticide and herbicide use is measured by total pounds of active ingredients applied during the crop year; that is, a sum of active ingredients in all products used. Insecticide use patterns differed significantly depending on whether the previous crop was corn or soybeans. The monoculture (3-year) corn cropping system registered the largest rate of insecticide use, averaging 0.81 pounds per acre across all corn acres (and 1.20 pounds per acre on treated acres). In fields where corn was planted in 1989 and 1990 but not in 1988, average insecticide use dropped to 0.71 pounds per acre across all acres (and to 1.15 pounds per acre for treated acres). However, this estimated rate is not significantly different from monoculture corn at a 10 percent (α) probability level, using a standardized normal test.

When soybeans rather than corn were planted in 1989, only 0.14 pounds per acre of insecticide were used across all acres (and 0.93 pounds per acre among treated acres), a significant decline at a 1 percent probability level. This decline was generated through two sources: a lower application rate among treated acres (i.e., a decline from 1.20 to 0.93 pounds per acre) and a smaller portion of acres treated (62.3 percent

Table A-1. Agrichemical uses and cropping patterns

	Unit	Cropping patterns (1990-1989) Corn-soybean	Three-year Corn-corn	Two-year1/ Corn-corn	Corn-other2/
Number of Fields		720	326	181	238
Insecticide3/					
Overall					
Mean	lbs/a.	0.14	0.81	0.71	0.27
St. Dev.	lbs/a.	0.65	0.97	0.97	0.85
Fields treated		113	203	105	49
Percent treated	%	15.7	62.3	58.0	20.6
Mean	lbs/a.	0.93	1.20	1.15	1.08
St. Dev.	lbs/a.	0.67	0.87	0.93	1.19
Herbicide3/					
Overall					
Mean	lbs/a.	3.38	3.04	3.37	3.17
St. Dev.	lbs/a.	2.45	2.43	3.08	2.81
Fields treated		707	306	173	219
Percent treated	%	98.2	93.9	95.6	92.0
Mean	lbs/a.	3.44	3.23	3.48	3.35
St. Dev.	lbs/a.	2.45	2.36	3.02	2.69
Nitrogen					
Overall					
Mean	lbs/a.	140	146	133	111
St. Dev.	lbs/a.	96	95	111	108
Fields treated		707	324	178	219
Percent treated	%	98.2	99.4	98.3	92.0
Mean	lbs/a.	142	146	137	117
St. Dev.	lbs/a.	95	94	111	104

1/ Corn planted in 1989 and 1990 but not 1988. 2/ Crops other than corn or soybeans were planted in 1989. 3/ Levels of insecticide and herbicide applications are measured in pounds of active ingredients per acre applied during the crop year.

versus 15.7 percent). A chi-squared test also revealed that the portion of corn acres treated in the corn-soybean system (i.e., 15.7 percent) was statistically lower than in the corn-corn system (62.3 percent) at a 1 percent probability level.

Among the 238 fields where neither corn nor soybeans were planted in 1989 (the last category in table A-1), an average of 0.27 pounds per acre of insecticides was applied, which is significantly lower than the 0.81 (and 0.71) pounds per acre applied in corn-corn systems. Furthermore, the portion of acres treated in the corn-other system was significantly lower than the corn-corn system.

Herbicides use was much more prevalent than insecticide use in 1990. Herbicides were applied to 96.7 percent of 1990 corn acres, whereas only 33.5 percent of acres were treated with insecticides. Herbicide use patterns were similar among the four cropping systems (5).

Herbicide use under the corn-soybean system appeared greater than monoculture corn, as measured by pounds of active ingredients per acre. However, the difference in herbicide use was not statistically significant (α = 5 percent) across rotations.

Corn farmers also apply nitrogen intensively. An estimated 98.2 percent of the corn acres in the 10 major producing States in 1990 were treated with nitrogen. As with herbicides, the portion of acres treated with nitrogen did not vary significantly across the corn-soybean, corn-corn, and corn-other cropping patterns. However, a smaller amount of nitrogen was applied in the fields where neither corn nor soybeans were planted (mainly in fallow or planted alfalfa) than in the fields where either corn or soybeans were planted.

Econometric Results and Implications

Many production practices recorded at the field level in the Cropping Practices Survey are expected to influence yields. The survey data were augmented with weather data as well as soil and land characteristics to estimate corn input-output relationships. The Cobb-Douglas specification was chosen in the preliminary analysis of input-output relationships. Further analysis will focus on model specification, including both variable and functional form selection.

Table 2 lists parameter estimates, t-values, and other summary statistics of the estimated input-output relationship. The independent variables have signs consistent with *a priori* expectations and are significant at a 5 percent probability level with the exception of four variables (the corn-other cropping system, insecticide use, herbicide use, and tillage passes).

Cropping Patterns

Ten cropping patterns were originally considered in the analysis, but were combined into three because the 1988 crop was not found to significantly affect the 1990 corn yields. The three selected patterns were distinguished by 1989 crops of corn, soybeans, and others (termed corn-corn, corn-soybean, and corn-other hereafter). The corn-corn pattern combines the 3- and 2-year continuous corn systems listed in table A-1, because their difference in affecting yields was not found to be statistically significant.

Dummy variables were used to represent different cropping patterns. The corn-corn pattern was excluded so that coefficients of corn-soybean and corn-other indicate yield effects relative to the corn-corn pattern. The corn-corn pattern had yields averaging 3.7 percent lower than the corn-soybean pattern. The corn-corn pattern had higher yields than the corn-other pattern but the difference was not statistically significant. The corn-other variable was kept to maintain the distinction between the corn-soybean and corn-corn patterns.

By rotating soybeans with corn, farmers gained higher yields (holding other input levels constant). Growing soybeans before corn likely increases nitrogen in the soil and breaks pest life cycles. Interaction terms between cropping patterns and agrichemical inputs (nitrogen, insecticides, and herbicides, all in logarithmic terms) were not found to be significant, suggesting no significant interaction between cropping patterns and agrichemicals in affecting corn yields.

Agrichemicals

Nitrogen use increased yields with an output elasticity of 2.1 percent. Similarly, the frequency of fertilizer applications increased yields. The use of pesticides (insecticides and herbicides) had positive effects on corn yields. However, the effects were not statistically significant at a 10 percent probability level. Because summing up active ingredients for all insecticide and herbicide products does not account for different efficacy levels among different products, the effects of pesticide use were further investigated by treating their uses as yes/no dummy variables. Again, the use of insecticides and herbicides had a positive effect on corn yields and their t-values were around 1.4. The positive and insignificant effect of insecticide use on corn yields is consistent with previous findings (4,5).

Positive and insignificant coefficients on the insecticide and herbicide variables might be expected because these inputs are typically applied to minimize loss not increase yields. Under the condition that farmers apply sufficient pesticides to minimize crop damage from pests, yields do not vary according to pesticide application rates.

Hanthorn and Duffy (5) reported a positive and significant impact of herbicide use on corn yields. A plausible explanation for their result is that increases in herbicide applications could be related to weather. For example, above average precipitation may boost yields but may require additional herbicide applications.

Substitutability of Crop Rotations for Agrichemicals

Agrichemical use patterns (table A-1) and the estimated input-output relationship (table A-2) can be used to assess possible reductions in agrichemical use and the subsequent yield changes when corn farmers rotate corn with other crops.

Results suggest that when a corn-soybean pattern replaces the corn-corn system, yields increase by 3.7 percent (or 4.6 bushels per acre for an average yield of 125 bushels per acre) while insecticide use will decrease from 0.77 pounds per acre (the average of 2 and 3 years of continuous corn) to 0.14 pounds per acre.

There were over 22 million acres of continuous corn patterns in the ten major producing States in 1990. If a quarter of the 22 million acres (i.e., 5.5 million acres) of corn planted in 1990 were to switch to soybean production in 1991 and then rotate to corn in 1992, the 1992 insecticide use on these 22 million acres would be 3.5 million pounds (20 percent) less than the monoculture corn pattern. Meanwhile, 1992 corn production would be 25.3 million bushels higher. However, the 1991 corn (soybean) output would decrease (increase) substantially because soybeans rather than corn are grown on the 5.5 million acres.

Table A-2. Corn input-output relationship:
1990 corn cropping practices survey data

	Cobb-Douglas functional form	
Variable	Coefficient	T-Value
Irrigated	0.1435	5.54
Seed quantity	0.5984	12.42
Lake region	0.1147	4.15
Corn Belt region	0.1075	4.48
Corn-soybean pattern	0.0371	2.76
Corn-other pattern	-0.0191	0.96
Manure	0.0430	2.94
Slope length	0.0451	4.13
Nitrogen	0.0212	3.45
Nitrogen inhibitor	0.0343	2.21
Insecticide	0.0036	1.34
Herbicide	0.0069	1.48
Tillage passes	0.0089	1.93
Commodity program (grains)	0.0213	2.04
Planting date	-0.4213	8.78
KFACT	-0.1383	2.53
TFACT	0.2109	3.08
Water holding Capacity	0.4078	5.69
Precipitation in August	0.0359	2.52
Fertilizer application freq.	0.0227	3.83
Constant	-1.6566	2.69

$R^2 = 0.46$, $\bar{R}^2 = 0.45$

Increases in soybean production and decreases in corn production are expected to depress soybean prices and bid up corn prices, a demand and supply realignment that works against crop rotations. In addition, there are an array of factors (economic, physical, operational, etc.) that limit cropping diversity. When continuous corn is replaced by corn-other pattern, insecticide use would potentially decline from 0.77 pounds per acre to slightly more than 0.27 pounds per acre, a more than 60 percent reduction.

Herbicide use patterns were similar across different cropping patterns in 1990. The estimated corn input-output relationship indicates that herbicide use did not significantly affect corn yields in 1990, probably because of sufficient herbicide application in 1990. Therefore, results of this study can not be used to establish the substitutability of cropping patterns for herbicide use. Field experimentations of different herbicide application rates on corn yields are needed to establish the substitutability between crop rotations and herbicide use.

The substitutability of a corn-soybean pattern for nitrogen use can be examined by comparing their coefficients. The output elasticity for nitrogen is 0.021, suggesting an increase in nitrogen use by 1 percent (or about 1.4 pounds) improves corn yields by 0.021 percent (0.026 bushels per acre). A switch from a corn-corn pattern to a corn-soybean pattern increases yields by 4.6 bushels per acre, ceteris paribus. Therefore, results of this study indicate that nitrogen use can be reduced significantly by crop rotation without reducing yields.

The potential reduction in nitrogen applications attributable from crop rotations is not calculated here because the nitrogen application would fall in a range not practiced by farmers. Furthermore, the specification for a corn input-output relationship (the selection of functional form and variables) is still an unresolved issue so that the results are preliminary (6).

Parameter Estimates of Other Inputs

The number of pesticide applications and the number of weed cultivations did not significantly affect 1990 corn yields, but the number of tillage passes improved yields. In addition to control weed, tillage may also improve soil permeability and growing conditions, such as temperature, in the root zone.

A nitrogen inhibitor is a chemical that slows down leaching of nitrogen and hence improves nitrogen efficacy. The application of a nitrogen inhibitor was identified but not the level of use. The use of a nitrogen inhibitor was estimated to increase corn yields by 3.4 percent (or slightly more than $9 per acre in 1990). A nitrogen inhibitor was applied on only 139 out of 1,465 fields sampled in the Cropping Practices Survey, 8.57 percent of the corn acres. Among the 1,465 observations, 211 applied manure. Manure treated acres were highest in Wisconsin (41 percent) and lowest in Missouri (3 percent). The application of manure increased yields by 4.3 percent.

Temperatures and precipitation in July were found to influence corn yields in 1988 and 1989 (4). In 1990, temperatures in June, July, or August were not found to have significantly affected corn yields. Precipitation in August, not July or June, was found to increase yields. Five soil and land characteristics (water holding capacity, permeability, slope length, soil erodibility factor [TFACT], and soil loss tolerance factor [KFACT]) from National Resource Inventory were included in the analysis. With the exception of permeability, these soil and land characteristics had significant impacts on corn yields.

Irrigation appeared to have a positive impact on corn yields with most irrigated corn acres being in Nebraska. Seeding rates significantly increased corn yields. Those who participated in the 1990 commodity support program for feed grains also had higher yields. The results are reasonable because farmers likely set aside less productive land when enrolling in the support program. Planting date delays resulted in lower yields.

Summary

Health and environmental concerns have encouraged public decisionmakers and the private sector to examine ways to systematically reduce the use of chemicals in agriculture. Crop rotations provide well-documented economic and environment benefits to agricultural producers (7). Current agricultural policies provide some incentive and flexibility to promote crop rotation.

Continuous corn cropping patterns use more insecticides than alternative patterns. Per acre insecticide use for 3-year continuous corn was 0.81 pounds, compared with 0.14 pounds for the corn-soybean pattern, suggesting that insecticide use could be reduced substantially through crop rotations. Because of similar herbicide use patterns among different cropping patterns and because of the statistically insignificant effect of herbicide (and insecticide) use on corn yields, the substitutability of crop rotations for herbicide use cannot be addressed in this study.

Empirical results also suggest that certain crop patterns, such as corn-soybean, can potentially reduce nitrogen use. The above conclusions are tentative as the econometric analysis of corn input-output relationships needs refinement. Furthermore, the statistical analysis of pesticide use patterns across patterns can be improved by comparing use patterns by product rather than total active ingredients. Some products used in a particular cropping pattern cannot be applied in

other patterns and different products may have different effects on human health and the environment.

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Fertilizer Application Timing

by

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Abstract: The number and timing of fertilizer applications used in the production of 1990 corn, cotton, rice, soybeans, and wheat were determined from a survey of the major producing States. The average number of fertilizer treatments ranged from 1.15 per acre for soybeans to 2.09 for corn and 2.32 for rice. Most fertilizer applied to winter wheat was in the fall before seeding, whereas the other crops received most of their fertilizer in the spring before seeding.

Keywords: Timing of fertilizer applications, acre-treatments, nitrogen, phosphate, potash

There is widespread public concern that agricultural practices are contributing to the contamination of the Nation's surface water and ground water. However, the source of most agriculturally induced pollution cannot be identified by farm (10). Concern about possible fertilizer and pesticide contamination of ground water has already led to numerous policy proposals affecting agriculture. The 1987 Water Quality Act, for example, instructs States to identify non-point-source pollution contributing to waterway degradation and to recommend "best management practices" to improve waterway quality (9). Consequently, many States have placed major emphasis on management practices to reduce ground and surface water contamination. These practices include, but are not limited to, crop rotations, conservation tillage, contouring, terracing, soil testing, and timing and placement of fertilizer nutrients.

Studies suggest that properly timed fertilizer applications, especially nitrogen, can increase yields, improve economic returns, and reduce leaching (1, 2, 3, 4, 5, 6). If applications are properly timed more fertilizer is available for use when crop requirements are highest and fewer nutrients run off into surface water or leach into underground aquifers. Properly timed nutrient applications have the potential to increase yields and economic returns, and decrease environmental contamination.

During field preparations and the growing season, many major crops receive more than one application. Corn, for example, often receives a mixed fertilizer during or before planting, and a second application after emergence of the seedlings (7). In contrast, soybeans are generally treated only once with fertilizer; however, a recent study in Georgia suggests that late season nitrogen applications can increase yields (4).

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Fertilizer application data on corn, cotton, rice, soybeans, and wheat were obtained in the 1990 Cropping Practices Survey conducted by USDA's National Agricultural Statistics Service. The survey covers the principal producing States, which account for 79-86 percent of the planted acres (harvested acres for winter wheat) of these crops. Information on the timing of nutrient applications, using 1988 data, was published in an earlier report (11).

Number of Treatments

In the 10 corn States surveyed (representing 58.8 million acres of planted corn), an average of 2.09 fertilizer acre-treatments were made in 1990, the second highest among the selected crops (table B-1). Of the estimated 57 million corn acres treated in the 10 States, 28 percent were treated once, 41 percent twice, and 26 percent three times.

In contrast, soybeans received the lowest average number of acre-treatments—1.15. In the 14 surveyed States, 78 percent of the estimated 15 million soybean acres treated received only one application of fertilizer, while 21 percent received two applications. Fertilizer acre-treatments averaged 1.77 for cotton, 2.32 for rice, and on wheat acres ranged from 1.42 (durum wheat) to 1.58 (winter wheat).

Table B-1--Percent of selected crop acres treated with fertilizer by number of treatments, 1990 1/

Crop	Number of treatments: 1	2	3	4	>4	Average acre-treatments
	Percent 2/					
Corn	28	41	26	5	0	2.09
Cotton	50	38	10	2	0	1.77
Rice	22	38	30	9	0	2.33
Soybeans	78	21	1	nr	#	1.15
Wheat:						
Winter	52	39	8	1	#	1.58
Spring	56	40	4	nr	nr	1.49
Durum	58	42	nr	nr	nr	1.42

nr = None reported. # = Less than 0.5 percent.

1/ Specific States surveyed for each crop are listed in tables B-2 through B-6. 2/ May not sum to 100 due to rounding.

Table B-2--Distribution of nutrient application rates on corn by time of application, 1990

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
IL	10,700	38	92	7	26	37	37	7	#	51	50	6	#
IN	5,600	9	53	20	57	14	21	39	#	38	60	13	1
IA	12,800	36	75	4	13	26	24	7	#	39	29	6	1
MI	2,400	8	37	23	55	nr	8	44	#	18	46	30	2
MN	6,700	32	61	9	11	10	21	19	#	20	32	16	1
MO	2,100	27	83	4	19	13	39	5	1	19	54	5	1
NE	7,700	42	61	13	28	4	5	22	#	3	6	12	1
OH	3,700	11	44	32	65	9	11	50	1	38	39	23	1
SD	3,400	19	36	9	15	10	17	15	#	6	14	3	#
WI	3,700	6	34	22	17	2	6	43	#	6	19	49	1
Area	58,800	28	65	12	27	18	21	21	#	32	37	14	1

nr = None reported. # = Less than 0.5 pounds.

Timing of Applications

There are numerous reasons why growers split their fertilizer applications, the most important of which is the plant's nutrient requirements and/or type of fertilizer used. Applications may also be split to reduce potential environmental damage. Other factors may be more related to economic considerations, however. The price of fertilizer is typically higher in the spring than in the preceding fall due to seasonal demand factors. For example, during 1961-88, anhydrous ammonia, concentrated superphosphate, and potassium chloride prices paid by farmers averaged 6, 5, and 5 percent higher in the spring than in the preceding fall (13). Consequently, some farmers purchase and apply fertilizer in the fall to cut costs.

Farmers may also apply fertilizer more than once to make timely use of available resources. Aside from winter wheat, spring planting typically places high seasonal demands on a grower's time, machinery, and hired and nonhired labor. Therefore, to spread out the demand for these resources, the grower may decide to apply some fertilizer in the fall. Fall fertilization can also reduce risks associated with wet springs. Additionally, some forms of irrigation technology can easily provide more than one fertilizer application.

Data from the Cropping Practices Survey were used to determine the timing of fertilizer applications by crop and nutrient. The survey permits the timing of nutrient applications to be separated into four categories: (1) before seeding in the fall; (2) before seeding in the spring; (3) at seeding; and (4) after seeding. Average per-acre rates by nutrient were calculated for each of the four designated times for each selected crop. This breakdown allows an analysis of how the overall nutrient application rate for a particular crop is distributed over the time periods.

Corn

Fertilizer was applied to 97 percent of the 58.8 million corn acres planted in the 10 surveyed States in 1990: 97 percent of the acres received nitrogen, 85 percent received phosphate, and 77 percent received potash (12). Average application rates for those corn acres receiving a particular nutrient stood at 132 pounds per acre for nitrogen, 60 pounds for phosphate, and 84 pounds for potash.

Table B-2 indicates how these nutrients were distributed over the four time periods for the 1990 corn crop. An average of 28 pounds (21 percent) of nitrogen per acre was applied in the fall before seeding, 65 pounds (49 percent) in the spring before seeding, 12 pounds (9 percent) at seeding, and 27 pounds (21 percent) after seeding. Results were similar for phosphate and potash because in general most of these nutrients were applied before seeding in the spring. However, unlike nitrogen, little phosphate or potash was applied to corn after seeding.

The distribution of nutrient applications also varied among States. In Wisconsin, only 6, 2, and 6 pounds of total nitrogen, phosphate, and potash used, respectively, were applied in the fall. However, these amounts increased to 38, 37, and 51 pounds in Illinois, where fall weather conditions in 1989 encouraged fertilization. In contrast, 32 pounds of the nitrogen and 50 pounds of phosphate used in Ohio were applied at seeding.

Cotton, Rice, Soybeans, and Wheat

Tables B-3 through B-6 present the distributions of nutrient applications for cotton, rice, soybeans, and wheat. Although the nutrient distributions for these crops generally resemble those of corn, some differences are apparent. As with corn, most of the nutrients applied to cotton, rice, soybeans, and wheat were before seeding. However, in the case of cotton, only a small proportion of total nutrient use was applied at seeding. Very little fertilizer was applied to soybeans and spring wheat after seeding. However, most nitrogen was ap-

Table B-3--Distribution of nutrient application rates on cotton by time of application, 1990

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
AZ	340	16	9	2	129	5	28	nr	34	7	nr	nr	14
AR	760	6	32	#	40	6	27	#	2	9	45	1	3
CA	1,050	47	27	7	59	44	22	#	2	9	26	nr	4
LA	780	14	28	1	34	7	30	1	10	11	38	nr	13
MS	1,200	23	19	5	63	22	22	3	3	35	38	#	5
TX	5,600	19	21	3	17	17	18	2	3	9	6	nr	2
Area	9,730	21	23	4	38	17	22	1	5	15	27	#	5

nr = None reported. # = Less than 0.5 pounds.

Table B-4--Distribution of nutrient application rates on rice by time of application, 1990

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
AR	1,230	5	9	2	98	21	24	nr	1	24	29	1	2
LA	570	4	10	5	96	1	17	3	23	1	19	4	22
Area	1,800	5	9	3	97	7	19	2	17	8	22	3	15

nr = None reported. # = Less than 0.5 pounds.

Table B-5--Distribution of nutrient application rates on soybeans by time of application, 1990

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
AL	3,100	9	29	nr	1	28	19	3	2	38	19	3	7
GA	900	6	10	1	2	14	24	2	#	25	40	3	1
IL	9,200	3	16	5	1	22	30	7	nr	41	48	6	nr
IN	4,300	4	7	5	#	16	14	10	1	39	41	10	1
IA	8,000	6	18	1	8	22	15	2	#	28	26	2	#
KY	1,250	10	24	4	2	28	35	6	3	39	38	7	#
LA	1,800	2	20	1	1	7	32	3	2	4	42	5	4
MN	4,600	5	6	4	1	12	16	6	nr	14	42	7	nr
MS	2,100	29	9	nr	5	25	14	nr	nr	35	32	nr	nr
MO	4,200	14	5	2	nr	13	23	5	nr	23	31	9	nr
NE	2,400	17	9	3	2	14	14	13	nr	12	20	nr	nr
NC	1,400	3	8	4	1	6	23	11	1	14	46	22	3
OH	3,700	2	5	3	#	18	22	8	#	40	53	13	#
TN	1,300	2	25	2	1	4	29	6	3	4	40	7	5
Area	48,250	6	13	3	2	17	23	6	1	31	41	8	1

nr = None reported. # = Less than 0.5 pounds.

plied to rice after seeding. For winter wheat a significant portion is applied after planting.

Fertilizer Treatments

Fertilizer use on corn, cotton, rice, soybeans, and wheat represents about 70 percent of all fertilizer use. During the 1989/90 fertilizer year (July /June), U.S. farmers applied to these crops over 66 percent of all nitrogen, 74 percent of all phosphates, and 68 percent of all potash.

U.S. farmers use more fertilizer on corn than any other crop (12, 14). During the 1989/90 fertilizer year, they applied an estimated 9.0 million tons of primary plant nutrients to their corn acres, or about 44 percent of the 20.6 million tons of nutrients. Specifically, corn accounted for an estimated 4.7 million tons of nitrogen or 43 percent of the 11.1 million tons used by all crops, 1.9 million tons of phosphate or 44 percent of the 4.3 million tons used, and 2.4 million tons of potash or 45 percent of the 5.2 million tons used in 1989/90.

Tables B-2 through B-6 show how, on average, the quantities of each nutrient applied to corn, cotton, rice, soybeans, and wheat, respectively, in 1990 were distributed throughout the production season. Although the tables provide useful information, a more detailed analysis of nutrient use by time of application supplies additional data that may be used to develop policies to combat surface and ground water contamination. These statistics include: (1) the proportion of acres receiving fertilizer during a particular time period, by nutrient; and (2) the average nutrient application rate of only those acres that received a particular nutrient during any selected time period.

Tables B-7, B-9, B-11, B-13, and B-15 show the proportion of acres for corn, cotton, rice, soybeans, and wheat that

received fertilizer in each time period by nutrient. For example, of the corn acres that received nitrogen (table B-7), 28 percent received some in the fall before seeding, 57 percent received some in the spring before seeding, 43 percent received some at seeding, and 26 percent received some after seeding. Since farmers can apply fertilizer during one or more time periods, the sum of these percentages exceeds 100 for each nutrient. Similar evaluations can be done for the other crops.

Further evaluation of the data suggests that fall fertilization on some crop acreage has the potential to cause environmental problems. Tables B-8, B-10, B-12, B-14, and B-16 show average nutrient application rates for only those acres that received a particular nutrient during a selected time period for corn, cotton, rice, soybeans, and wheat, respectively. For example, the nitrogen application rate for corn acres receiving nitrogen in the fall before seeding averaged 102 pounds per acre (table B-8). This was by far the most applied in the fall for any crop studied. Overall, more than 21 percent of the total nitrogen used on the 1990 corn crop was applied in the fall.

Nitrogen application rates for corn growers who applied fertilizer on 57 percent of the corn acres before seeding in the spring averaged 114 pounds per acre, the highest of any crop. The total amount of these applications in this time period represented about 49 percent of the nitrogen applied during the year on corn.

About 9 percent of the nitrogen applied to corn during the year was applied at seeding; another 21 percent was applied after seeding. The average application rate for those growers who applied at seeding and after seeding was 27 and 105 pounds per acre, respectively. Because different numbers of farmers applied fertilizer during the different time periods, these averages are not additive, and their sum does not equal the yearly application rate for all farmers applying fertilizer during the year.

Results were similar for phosphate and potash applied to corn acres, but the average application rates for these nutrients were highest in the fall. Growers who applied phosphate in the fall used an average of 69 pounds per acre, while those who used potash applied an average of 103 pounds per acre. In addition, few corn acres received either phosphate or potash after seeding.

Average nutrient application rates by time of application also varied significantly among States. Fall nitrogen applications on corn ranged from an average of 60 pounds in Indiana to 133 pounds in Minnesota (table B-8). Nebraska, which is experiencing significant ground water problems, averaged 125 pounds. Similarly, fall applications of phosphate varied from 36 to 95 pounds, and those for potash ranged from 19 to 168 pounds among States.

Tables B-8, B-10, B-12, B-14, and B-16 have important implications for determining best management practices for effective timing of fertilizer applications. For example, spring 1990 denitrification (the gaseous loss of nitrogen) and leaching due to an excessively wet spring in some areas may have prohibited the crop from using a substantial portion of the nitrogen applied in the fall. Denitrification is a major mechanism of nitrogen loss in waterlogged and poorly aerated soils in which aerobic and anaerobic conditions fluctuate (1, 8).

The loss of nitrogen through percolation is also possible since soils and subsoils have little capacity to retain nitrate. In contrast, during drought conditions, leaching is reduced since nutrient movement in dry soils is more difficult. Therefore, nitrate loss depends on the concentration of nitrogen escaping below the root zone and the flux of percolating water moving it. This phenomenon is particularly evident until the soil freezes during the winter or after it thaws in the spring. The time between fall fertilization and spring planting increases the likelihood that nitrogen will percolate into ground water when it is applied in the fall (1, 2).

Implications

The timing of fertilizer applications has important agronomic, economic, and environmental ramifications. Price incentives, resource limitations, and the potential for a wet spring, among other things, can encourage farmers to apply some fertilizer in the fall. Using phosphate or potash in the fall does not pose an environmental problem because these nutrients are relatively immobile in soils that are not prone to leaching.

Nitrogen used for fall fertilization is subject to denitrification and may run off into surface water or leach into underground aquifers. In the 10 major corn producing States, 28 percent of the acres planted to corn (16 million acres) were treated with nitrogen in the fall. This area received an average of 102 pounds of nitrogen per acre, and accounted for 21 percent of all the nitrogen applied to corn. Although only 21 percent of the total nitrogen used was applied in the fall, average nitrogen application rates were relatively high. However, data used in this analysis did not include information to measure surface water or ground water contamination.

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Table B-6--Distribution of nutrient application rates on wheat by time of application, 1990

State	Acres 1/	Nitrogen				Phosphate				Potash			
		Before seeding		At seeding	After seeding	Before seeding		At seeding	After seeding	Before seeding		At seeding	After seeding
		Fall	Spring			Fall	Spring			Fall	Spring		
	1,000	Pounds per treated acre											
						Winter wheat							
AR	1,300	9	na	1	89	31	na	6	4	44	na	6	5
CO	2,550	34	na	2	5	17	na	2	3	nr	na	nr	nr
IL	1,950	24	na	2	59	63	na	6	na	81	na	8	2
KS	11,800	34	na	4	12	19	na	10	1	5	na	15	1
MO	2,000	26	na	8	51	36	na	13	3	48	na	16	7
MT	2,600	27	na	10	10	2	na	24	1	3	na	14	1
NE	2,250	40	na	1	10	22	na	5	#	nr	na	nr	6
OH	1,350	22	na	3	50	58	na	4	3	54	na	7	9
OK	6,300	48	na	5	12	21	na	12	1	12	na	13	nr
SD	1,700	8	na	8	20	8	na	14	2	3	na	2	nr
TX	4,200	55	na	13	20	27	na	6	3	9	na	1	nr
WA	2,200	52	na	10	3	12	na	7	#	nr	na	nr	2
Area	40,200	36	na	5	21	27	na	10	1	42	na	11	4
						Spring wheat							
MN	2,800	47	26	7	2	4	17	17	4	5	16	11	3
MT	2,800	10	14	16	nr	5	7	18	nr	2	2	4	nr
ND	8,000	23	11	11	#	2	3	26	#	2	3	8	nr
SD	2,200	9	18	12	1	4	16	9	nr	nr	5	2	nr
Area	15,800	25	16	11	1	3	8	21	1	3	9	9	2
						Durum wheat							
ND	3,100	21	5	9	nr	1	1	23	nr	1	2	5	nr

na = Not applicable. nr = None reported. id = Insufficient data. # = Less than 0.5 pounds.

1/ Harvested acres for winter wheat and planted acres for spring and durum wheat.

Table B-7--Percent of corn acres receiving fertilizer by nutrient and time of application, 1990

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Percent 1/											
IL	10,700	37	68	14	20	42	48	14	*	44	48	10	*
IN	5,600	14	53	73	50	19	36	74	1	28	57	31	1
IA	12,800	38	67	18	14	41	43	22	1	43	44	19	1
MI	2,400	6	40	87	48	nr	19	86	2	11	47	62	3
MN	6,700	30	61	51	13	19	38	54	2	24	44	42	2
MO	2,100	21	61	11	18	22	66	11	3	22	66	11	3
NE	7,700	34	49	55	31	12	14	75	1	12	16	78	3
OH	3,700	14	38	83	52	16	16	84	3	32	35	60	3
SD	3,400	26	48	32	21	26	38	37	2	32	41	27	3
WI	3,700	4	38	89	25	2	12	91	2	4	21	89	2
Area	58,800	28	57	43	26	26	35	48	1	31	43	35	1

nr = None reported. * = Less than 0.5 percent.

1/ The sum of the percentages exceeds 100 for each nutrient because growers can apply fertilizer during one or more time periods.

Table B-8--Average application rates on corn for those acres receiving specific nutrients by time of application, 1990

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
IL	10,700	103	136	47	130	89	79	47	50	117	105	55	60
IN	5,600	60	101	28	114	75	58	52	68	135	106	41	150
IA	12,800	96	111	19	91	64	56	34	57	91	66	31	67
MI	2,400	133	92	27	115	nr	44	51	4	168	98	48	64
MN	6,700	108	101	18	83	52	56	36	37	83	73	38	43
MO	2,100	130	135	35	106	58	60	43	39	88	82	44	42
NE	7,700	125	124	23	91	36	33	30	9	26	35	16	42
OH	3,700	78	115	39	124	55	71	60	48	117	111	39	43
SD	3,400	71	76	30	73	36	44	41	7	19	35	12	2
WI	3,700	131	88	25	70	95	47	47	44	139	90	54	50
Area	58,800	102	114	27	105	69	61	44	38	103	87	39	54

nr = None reported.

Table B-9--Percent of cotton acres receiving fertilizer by nutrient and time of application, 1990

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Percent 1/											
AZ	340	18	26	4	89	11	38	nr	57	33	nr	nr	67
AR	760	17	68	13	71	19	77	1	6	18	78	2	6
CA	1,050	46	34	8	55	60	37	2	5	33	50	nr	17
LA	780	20	46	2	57	21	57	4	30	21	58	nr	30
MS	1,200	31	37	8	80	41	46	7	7	42	48	1	10
TX	5,600	40	44	8	32	42	46	3	14	51	41	nr	14
Area	9,730	35	44	8	51	37	50	3	15	37	53	1	15

nr = None reported. * = Less than 0.5 percent.

1/ The sum of the percentages exceeds 100 for each nutrient because growers can apply fertilizer during one or more time periods.

Table B-10--Average application rates on cotton for acres receiving specific nutrients by time of application, 1990

State	Acres planted	Nitrogen: Before seeding Fall	Nitrogen: Before seeding Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding Fall	Phosphate: Before seeding Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding Fall	Potash: Before seeding Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
AZ	340	88	34	47	145	50	74	nr	60	22	nr	nr	20
AR	760	32	46	62	56	33	35	26	37	47	57	43	42
CA	1,050	101	79	94	107	73	60	11	37	28	53	nr	26
LA	780	71	60	24	60	34	54	39	32	52	66	nr	44
MS	1,200	73	51	57	78	55	48	43	41	82	79	25	54
TX	5,600	48	47	32	53	41	39	63	22	17	15	nr	17
Area	9,730	62	52	49	74	45	43	50	31	40	51	37	34

nr = None reported.

Table B-11--Percent of rice acres receiving fertilizer by nutrient and time of application, 1990

State	Acres planted	Nitrogen: Before seeding Fall	Nitrogen: Before seeding Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding Fall	Phosphate: Before seeding Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding Fall	Potash: Before seeding Spring	Potash: At seeding	Potash: After seeding
	1,000	Percent 1/											
AR	1,230	12	14	4	91	51	46	nr	3	49	47	2	2
LA	570	5	20	6	95	4	31	6	58	2	32	7	58
Area	1,800	10	16	4	92	18	36	5	42	17	37	6	40

nr = none reported.

1/ The sum of the percentages exceeds 100 for each nutrient because growers can apply fertilizer during one or more time periods.

Table B-12--Average application rates on rice for acres receiving specific nutrients by time of application, 1990

State	Acres planted	Nitrogen: Before seeding Fall	Nitrogen: Before seeding Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding Fall	Phosphate: Before seeding Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding Fall	Potash: Before seeding Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
AR	1,230	47	64	50	108	42	52	nr	45	48	63	60	90
LA	570	79	51	71	101	36	55	49	39	46	59	51	37
Area	1,800	53	59	60	106	41	54	49	39	48	60	52	38

nr = None reported.

Table B-13--Percent of soybeans acres receiving fertilizer by nutrient and time of application, 1990

State	Acres planted	Nitrogen: Before seeding Fall	Nitrogen: Before seeding Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding Fall	Phosphate: Before seeding Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding Fall	Potash: Before seeding Spring	Potash: At seeding	Potash: After seeding
	1,000	Percent 1/											
AR	3,100	50	56	nr	6	58	39	3	6	54	31	3	11
GA	900	35	55	9	4	35	56	7	1	35	57	7	1
IL	9,200	14	54	21	11	34	53	13	nr	38	52	10	nr
IN	4,300	24	25	53	5	30	33	38	4	35	42	29	3
IA	8,000	34	39	14	14	44	38	17	2	41	43	15	1
KY	1,250	23	65	13	4	38	48	11	3	41	46	11	2
LA	1,800	19	69	6	6	16	72	6	6	10	76	7	7
MN	4,600	23	38	38	8	23	38	38	nr	21	43	36	nr
MS	2,100	71	14	nr	14	67	33	nr	nr	60	40	nr	nr
MO	4,200	27	55	18	nr	30	55	15	nr	29	57	14	nr
NE	2,400	31	31	31	8	30	40	30	nr	50	50	nr	nr
NC	1,400	17	52	30	1	15	54	30	2	18	53	29	2
OH	3,700	13	48	30	9	33	42	21	6	34	49	15	4
TN	1,300	9	70	15	9	8	69	15	8	7	69	16	7
Area	48,250	24	47	23	8	33	48	18	3	34	49	15	2

nr = None reported. * = Less than 0.5 pounds.

1/ The sum of the percentages exceeds 100 for each nutrient because growers can apply fertilizer during one or more time periods.

Table B-14--Average application rates on soybeans for acres receiving specific nutrients by time of application, 1990

State	Acres planted	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
AR	3,100	18	51	nr	16	49	49	96	40	70	60	96	62
GA	900	17	18	15	48	40	42	31	30	71	71	48	45
IL	9,200	23	29	25	11	65	56	52	nr	107	94	62	nr
IN	4,300	18	27	9	5	54	43	27	16	111	98	33	36
IA	8,000	18	47	8	57	51	41	14	6	68	60	15	3
KY	1,250	45	37	32	38	73	72	52	104	94	82	65	24
LA	1,800	11	29	9	10	44	45	44	45	40	55	78	51
MN	4,600	20	16	10	15	52	41	15	nr	63	97	20	nr
MS	2,100	41	64	nr	33	38	41	nr	nr	59	80	nr	nr
MO	4,200	50	10	10	nr	44	41	36	nr	82	54	60	nr
NE	2,400	55	31	11	28	47	34	42	nr	24	40	nr	nr
NC	1,400	15	15	13	99	36	44	36	35	79	88	76	126
OH	3,700	19	11	11	1	55	52	36	2	117	107	85	2
TN	1,300	18	36	15	10	49	41	40	40	55	58	45	64
Area	48,250	25	28	13	24	53	48	34	30	91	83	51	46

nr = None reported.

Table B-15--Percent of wheat acres receiving fertilizer by nutrient and time of application, 1990

State	Acres 1/	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Percent 2/											
		Winter wheat											
AR	1,300	26	na	5	92	75	na	15	9	75	na	15	9
CO	2,550	82	na	5	20	74	na	13	13	nr	na	nr	nr
IL	1,950	74	na	7	82	92	na	8	na	90	na	7	2
KS	11,800	76	na	20	38	59	na	38	5	28	na	63	8
MO	2,000	58	na	23	68	69	na	27	8	66	na	27	12
MT	2,600	48	na	74	23	11	na	86	4	17	na	75	8
NE	2,250	84	na	9	26	75	na	20	6	nr	na	nr	100
OH	1,350	86	na	10	83	89	na	9	7	87	na	9	9
OK	6,300	80	na	28	41	57	na	40	4	51	na	49	nr
SD	1,700	29	na	40	49	35	na	59	6	50	na	50	nr
TX	4,200	75	na	22	34	71	na	22	8	83	na	17	nr
WA	2,200	87	na	17	13	63	na	40	3	nr	na	nr	100
Area	40,200	73	na	22	42	62	na	35	5	65	na	29	8
		Spring wheat											
MN	2,800	58	51	45	3	10	44	50	3	10	48	48	4
MT	2,800	15	30	70	nr	15	18	70	nr	17	16	67	nr
ND	8,000	39	23	76	1	6	11	85	2	10	19	76	nr
SD	2,200	20	50	37	7	13	48	39	nr	nr	67	33	nr
Area	15,800	38	34	63	2	9	24	69	2	10	35	60	2
		Durum wheat											
ND	3,100	36	16	88	nr	3	4	93	nr	11	11	78	nr

na = Not applicable. nr = None reported. id = Insufficient data. # = Less than 0.5 pounds.

1/ Harvested acres for winter wheat and planted acres for spring and durum wheat. 2/ The sum of percentages exceeds 100 for each nutrient because growers can apply fertilizer during one or more time periods.

Table B-16--Average application rates on wheat for acres receiving specific nutrients by time of application, 1990

State	Acres 1/	Nitrogen: Before seeding, Fall	Nitrogen: Before seeding, Spring	Nitrogen: At seeding	Nitrogen: After seeding	Phosphate: Before seeding, Fall	Phosphate: Before seeding, Spring	Phosphate: At seeding	Phosphate: After seeding	Potash: Before seeding, Fall	Potash: Before seeding, Spring	Potash: At seeding	Potash: After seeding
	1,000	Pounds per treated acre											
							Winter wheat						
AR	1,300	35	na	31	98	41	na	42	38	59	na	42	52
CO	2,550	41	na	31	26	23	na	18	22	nr	na	nr	nr
IL	1,950	33	na	32	72	74	na	72	nr	90	na	113	90
KS	11,800	44	na	19	32	32	na	26	15	18	na	23	10
MO	2,000	44	na	34	75	52	na	47	34	72	na	60	55
MT	2,600	57	na	14	43	23	na	28	25	19	na	18	9
NE	2,250	47	na	14	38	30	na	24	3	nr	na	nr	6
OH	1,350	25	na	31	61	65	na	52	44	63	na	79	97
OK	6,300	59	na	19	30	36	na	30	27	23	na	27	nr
SD	1,700	27	na	20	40	23	na	24	30	6	na	4	nr
TX	4,200	74	na	58	60	39	na	29	36	11	na	5	nr
WA	2,200	60	na	56	23	19	na	18	5	nr	na	nr	2
Area	40,200	50	na	24	50	43	na	30	26	64	na	38	49
							Spring wheat						
MN	2,800	82	51	16	84	45	39	35	109	47	33	22	81
MT	2,800	64	45	23	nr	32	37	26	nr	10	10	5	nr
ND	8,000	58	46	15	11	26	26	31	28	22	15	10	nr
SD	2,200	46	35	33	22	30	34	22	nr	nr	8	7	nr
Area	15,800	66	46	17	39	33	35	31	70	33	27	14	81
							Durum wheat						
ND	3,100	57	32	11	nr	35	30	25	nr	9	14	6	nr

na = Not applicable. nr = None reported. id = Insufficient data. # = Less than 0.5 pounds.

1/ Harvested acres for winter wheat and planted acres for spring and durum wheat.

Crop Sequences Among 1990 Major Field Crops and Associated Farm Program Participation

by

Mohinder Gill and Stan Daberkow[1]

Abstract: Cropping Practices Survey data for 1990 indicate farmers continue to extensively rotate the major field crops. Comparisons between 1989 and 1990 crop production patterns show very little overall change. However, monoculture cropping is still prevalent in certain crops and States and may be linked to past agricultural policy. The distribution of cropping patterns by farm program participation indicate that a large share of land enrolled in the 1990 cotton and corn programs was continuously cropped.

Keywords: Cropping patterns, pests, farm program participation, major field crops

Crops are typically rotated because of the inherent agronomic and economic benefits associated with various cropping sequences. These benefits can include control of pests, weeds, and diseases; maintenance of soil fertility; conservation of soil moisture; prevention of erosion; reduction of fertilizer, insecticide and herbicide use; and abatement of water pollution often associated with runoff and leaching (1,4,5). While crop rotation is widely practiced in the United States, farmers in certain parts of the country apparently perceive it to be either unprofitable or insufficiently profitable.

Another often cited barrier to cropping diversity is agricultural policies which may have encouraged continuous cropping (6). Prior to the 1990 farm bill, farmers participating in the support program could not easily change their cropping patterns without jeopardizing the amount of their program crop acreage eligible for payments. This was particularly true for farmers who had a large share of their cropland devoted to program crops.

Due to these policy constraints and the rising concerns about the perceived link between monoculture cropping and declines in water quality and food safety, policies have been changed to encourage more crop rotation. For example, the 1990 farm bill allows more planting flexibility, while protecting the crop acreage base. Specifically, producers are allowed to plant up to 25 percent of their crop acreage base to other crops without losing any base. Other provisions that could encourage crop rotation include the Agricultural Water Quality Incentive Program, the Integrated Farm Management Option, and increased authorizations for research on sustainable agriculture and integrated crop management systems.

This article uses Cropping Practices Survey (CPS) data for the major field crops grown in 1990 and examines the share of acreage on which various 3-year cropping patterns were practiced. Survey data indicate that for most areas of the United States farmers varied the crops planted from year-to-year over the 3-year period. In individual States, cropping patterns vary from year to year, but comparisons between 1989 and 1990 show patterns changed very little. However, for certain crops and States, the survey showed continuous cropping was widely practiced.

This article also examines the distribution of cropping patterns by farm program participation.[2] While the evidence does not necessarily imply that program participation leads to specific cropping patterns, especially when monoculture cropping is involved, it does indicate the level of association between program participation and selected cropping sequences.

Corn

In 1990, in the 10 major corn producing States surveyed, the two most common cropping sequences were continuous corn production and corn-soybean-corn, similar to 1989 (20). This pattern likely represents 2-year corn-soybean rotation. These two sequences were used on 65 percent of the 1990 acreage (Table C-1). Continuous corn was most common in Nebraska (59 percent), with 73 percent of the irrigated areas of the State following this pattern. Fixed investment in irrigation capital and heavy participation in the commodity programs likely contributed to a lack of crop diversity. Continuous cropping also was frequently used in Wisconsin (36

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[2]The CPS collects data on a field basis. Therefore, the information collected on farm program participation was asked in terms of whether the field in the survey was part of a farm enrolled in the one or more of the 1990 farm programs (i.e., feed grains, wheat, rice, or cotton).

Table C-1--Cropping patterns used on land producing corn, 1990

Previous crop								Nebraska						Area		
1989	1988	IL	IN	IA	MI	MN	MO	State	Dry	Irr.	OH	SD	WI	1990	1989	1988
		Million acres planted														
		10.7	5.6	12.8	2.4	6.7	2.1	7.7	2.3	4.6	3.7	3.4	3.7	58.8	57.9	53.2
		Percent														
Corn	Corn	18	20	21	26	15	16	59	22	73	15	10	36	25	23	26
Corn	Soybean	8	11	7	9	7	8	5	12	1	9	2	4	7	7	5
Corn	Alfalfa	1	1	2	3	3	1	1	2	nr	1	1	10	2	2	3
Corn	Other	*	3	2	10	2	5	3	3	2	3	4	6	3	4	3
Soybean	Corn	56	42	56	13	43	38	17	31	11	38	29	6	40	38	38
Soybean	Soybean	5	8	3	11	4	15	3	9	1	6	3	nr	5	5	4
Soybean	Other	4	4	2	3	7	4	nr	3	1	3	6	2	3	4	3
Fallow 1/	Other	3	5	2	7	2	8	3	7	1	10	3	5	3	4	2/
Alfalfa	Alfalfa	nr	*	3	1	5	2	nr	nr	nr	6	1	20	3	2	4
Alfalfa	Other	1	1	1	1	1	1	nr	nr	nr	3	nr	3	1	1	1
Wheat	Corn	nr	1	nr	1	1	nr	nr	nr	nr	nr	4	1	1	2	1
Wheat	Other	*	4	nr	2	4	1	1	1	nr	nr	10	1	2	4	3
Oats	Corn	1	nr	nr	nr	2	nr	2	6	nr	nr	12	1	2	1	1
Oats	Other	1	nr	1	3	2	nr	nr	nr	nr	nr	5	nr	1	1	1
Sub-total		98	100	100	90	98	97	92	96	90	98	88	95	98	98	94
Other	Other	2	0	0	10	2	3	8	4	10	2	12	5	2	2	6
Total		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

nr = None reported. * = less than 1 percent.

1/ No crops planted during this year. 2/ Included in other.

percent), Michigan (26 percent), Iowa (21 percent), Indiana (20 percent), and Illinois (18 percent).

Based on a survey of 1990 corn fields, the corn-soybean-corn rotation dominated in Iowa (56 percent), Illinois (56 percent), Minnesota (43 percent), Indiana (42 percent), and Ohio (38 percent). For all surveyed States, 40 percent of the 1990 corn land grew soybeans in 1989 and corn in 1988.

One advantage of a corn-soybean-corn rotation is the ability of soybeans to fix nitrogen in the soil, which may allow farmers to reduce commercial nitrogen applications on the succeeding corn crop. Alternating corn with soybeans also may help control weeds and insects (3). One of the most beneficial aspects of crop rotation is the control of insects that eat only one kind of food (8,9). Northern or western corn rootworm, corn root aphids, wireworms, and maize billbug are in this category (10,11,12). These pests can be controlled by rotating to crops on which the pest will not feed, such as legumes or small grains (8,13).

In Wisconsin, alfalfa rather than soybeans is alternated with corn. Alfalfa serves the same purpose as soybeans in a rotation and provides protein for dairy feed. In 1990, 20 percent of the land used to grow corn had been planted to alfalfa in the previous 2 years.

Overall, corn cropping patterns remained stable between 1989 and 1990. However, a significant change occurred in Missouri, where the share of corn-soybean-corn rotation increased 16 percentage points to about the same as in 1988 (20).

To examine corn cropping patterns by farm program participation, the CPS observations were divided into three categories: those fields that were part of farms enrolled only in the 1990 feed grain program; farms enrolled in both the 1990 feed grains and wheat programs; and farms not enrolled in any program or just in the wheat or cotton programs. A Chi-square test was performed to determine whether the distribution of cropping patterns differed significantly between any two farm program categories. In all comparisons, the cropping patterns were statistically different at the 1-percent level of confidence.

Farms enrolled only in the feed grain program exhibited different cropping patterns from those in the other two program groupings (table C-2). Continuous cropping and the corn-soybean-corn rotations were more prevalent in this category

Table C-2--Share of acres in commodity support program: On land producing corn in 1990

Previous crop 1989	1988	Feed grain program only	Feed grain & wheat program	Non-participant in feed grain program 1/
		Million acres planted		
		33.8	12.3	12.65
		---------Percent---------		
Corn	Corn	26	20	23
Corn	Soybeans	8	6	6
Corn	Other	3	6	7
Soybeans	Corn	47	29	32
Soybeans	Soybeans	3	7	6
Soybeans	Other	2	6	4
Fallow	Any	1	4	2
Alfalfa	Any	3	4	6
Wheat	Any	*	8	3
Oats	Any	2	2	3
Other		4	8	8
All		100	100	100

* = Less than 1 percent
1/ Includes corn land in farms enrolled only in 1990 wheat or cotton program.

than the others. However, somewhat surprisingly the proportion of monoculture corn among farms not in the program was only slightly smaller than the other program categories (i.e., 23 percent versus 26 percent and 20 percent). Those farms enrolled in both the feed grains and wheat programs were expected to have different cropping patterns from the other participation categories due to the necessity to plant corn and wheat in order to maintain program bases.

Soybeans

The two common cropping patterns practiced by farmers in the 14 major soybean producing States were: soybean-corn-soybean in the Northern States and continuous soybean production in the Southern States (table C-3). The soybean-corn-soybean pattern was particularly prevalent in Illinois (66 percent), Indiana (53 percent), Iowa (78 percent), Minnesota (59 percent), Nebraska (49 percent), and Ohio (45 percent). In these States, 58 percent of 1990 soybean producing acres used this practice.

The soybean-corn-soybean rotation pattern was common because soybeans compete economically with other crops and typically provide a natural source of nitrogen for the succeed-

Table C-3--Cropping patterns used on land producing soybeans, 1990

Previous crop 1989	1988	IL	IN	IA	MN	MO	NE	OH	1990 area (Northern States)	AR	GA	KY	LA	MS	NC	TN	1990 area (Southern States)
		Million acres planted								Million acres planted							
		9.2	4.3	8.0	4.6	4.2	2.4	3.7	36.4	3.1	0.9	1.25	1.8	2.1	1.4	1.3	11.85
		Percent								Percent							
Soybean	Corn	7	10	5	3	8	4	10	7	nr	7	10	nr	3	7	10	4
Soybean	Soybean	2	4	1	nr	14	1	9	4	22	18	11	48	50	9	28	29
Soybean	Other	1	*	nr	2	6	6	1	1	8	5	2	8	7	5	4	7
Corn	Corn	11	9	8	6	7	22	3	9	nr	2	5	nr	1	2	3	1
Corn	Soybean	66	53	78	59	25	49	45	58	nr	7	20	4	nr	15	7	6
Corn	Other	4	11	5	12	5	5	14	5	nr	2	1	nr	nr	8	nr	2
Fallow	Other	3	7	1	7	9	nr	8	3	3	4	4	6	5	9	3	5
Rice	Soybean	nr	nr	nr	nr	nr	nr	nr	nr	15	nr	nr	7	6	nr	nr	6
Rice	Other	nr	nr	nr	nr	1	nr	nr	*	6	nr	nr	5	1	nr	nr	3
3/	Soybean	1	nr	nr	nr	1	nr	2	*	4	8	1	1	2	3	6	3
3/	Other	1	2	nr	nr	4	nr	6	2	1	nr	2	nr	1	3	1	1
1990 double-cropped wheat-soybeans 2/																	
Corn	Soybean	nr	*	nr	nr	1	nr	nr	*	nr	1	9	1	nr	9	2	3
Corn	Other	nr	nr	nr	nr	nr	nr	nr	nr	1	nr	4	1	nr	6	2	2
Soybean	Soybean	1	nr	nr	nr	2	nr	nr	1	4	2	1	5	3	2	6	3
Soybean	Corn	1	1	nr	nr	1	nr	nr	*	nr	nr	9	nr	nr	1	1	1
Soybean	Other	nr	*	nr	nr	nr	nr	nr	*	4	3	nr	1	1	2	2	2
Fallow 1/	Soybean	2	1	nr	nr	2	nr	nr	1	4	nr	2	3	3	2	1	3
Fallow	Other	1	nr	nr	nr	nr	nr	3	*	2	1	1	nr	nr	3	3	1
Peanuts	Other	nr	nr	nr	nr	nr	nr	nr	nr	nr	10	nr	nr	nr	nr	nr	1
3/	Soybean	1	1	nr	nr	6	nr	nr	1	19	15	17	5	11	4	19	13
3/	Other	nr	nr	nr	nr	2	nr	nr	nr	1	2	2	nr	1	2	1	1
Sub-total		100	98	99	86	90	87	98	95	94	87	100	95	95	92	99	97
Other	Other	0	2	1	14	10	13	2	5	6	13	0	5	5	8	1	3
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

nr = none reported. * = less than 1 percent. 1/ No crops planted during this year. 2/ Winter wheat planted in fall 1989 and soybeans planted in spring/summer 1990. 3/ Winter wheat planted in fall 1988 and soybeans planted in spring/summer 1989.

ing crops. Yields of corn (and wheat) planted after soybeans are, on average, 5-10 percent higher than those planted after nonleguminous crops (1). Furthermore, rotations increased soybean yield over continuous cropping because soybean cyst nematodes were controlled (14). According to one study,the nematode population was reduced by rotating to nonhost crops, such as corn, wheat, cotton, small grains, and grain sorghum (15,16).

In southern States, such as Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, and Tennessee, continuous soybean production was used on 28 percent of the 1990 soybean producing acres. Continuous soybeans appear to be profitable in these States, although lack of program base acreage or soil characteristics may have limited the diversity of cropping patterns on some farms.

In Delta States — Arkansas, Louisiana, and Mississippi — rice was also used in soybean production rotations. This was done on 9 percent of the 1990 soybean acres. In Georgia, peanuts were a significant component of the soybean rotation. Ten percent of 1990 soybean acres grew peanuts in the preceding year.

Southern farmers extensively used a double cropping system with soybeans following winter wheat. Approximately 30 percent of the 1990 soybean acres were double cropped in the South (18). Besides producing two crops in a year, this system also provides an opportunity for minimum tillage soybean production, which reduces costs. Soybeans are often planted with no-till planters in wheat or other small grain stubble soon after the grain is harvested. While soybeans in the South receive more herbicide treatment than in the North, very little insecticide is used on southern soybeans (7).

Cotton

Continuous cotton cropping is widely practiced in the six major producing States (table C-4). Sixty-one percent of the 1990 cotton land grew cotton in the previous 2 years, which was slightly less than in 1989. In Mississippi, Louisiana, and Arkansas, 82, 74, and 71 percent, respectively, of the 1990 cotton land was in continuous cotton. In Arizona, Texas, and California, continuous cotton production was practiced on 50 to 56 percent of the cotton acres.

Sorghum rotated with cotton is popular in Texas while vegetables are commonly alternated with cotton in California. Soybeans are rotated with cotton mostly in Louisiana, Arkansas, and Missouri. Rotating cotton with grain sorghum, corn, or small grains reduces insects and disease problems, such as boll weevil, bollworm, tobacco budworm, pink bollworm and rootrot (19). About 40 percent of the losses attributed to cotton pests are traceable to the boll weevil (2). Cotton rotated with sorghum, for example, has been particularly useful in reducing boll weevil infestations.

Cotton fields in the survey belonged to farms which fell into one of three farm program categories: enrolled in the 1990 cotton program only; enrolled in the 1990 cotton and one or more other commodity programs; and not enrolled in the 1990 cotton program or enrolled only in the 1990 wheat, feed grains, and/or rice programs. Farms enrolled only in the cotton program were heavily involved in continuous cotton cropping, with over 75 percent of the cotton acreage planted to cotton 3 years in a row (table C-5). (All the program participation categories differ from one another at the 1-percent level of confidence, based on a Chi-square test). Because of the attractiveness of the cotton program continuous cotton is widely practiced in the cotton States surveyed.

Farms participating in the cotton and other commodity programs had a much lower share of acreage in continuous cotton (54 percent), compared to acreage enrolled solely in the cotton program. Those farms not enrolled in the 1990 cotton program had the lowest share of acres in continuous cotton (45 percent) of all the program categories. Based on these results, participation in the cotton program appears associated with continuous cropping patterns. However, even land enrolled in the cotton program tended to be continuously cropped, which may be linked to attempt to increase cotton base acreage.

Table C-4--Cropping patterns used on land producing cotton, 1990

Previous crop 1989	1988	AZ	AR	CA	LA	MS	TX	1990 area
		Million acres planted						
		0.34	0.76	1.05	0.78	1.20	5.6	9.73
		Percent						
Corn	Cotton	nr	2	nr	nr	1	6	4
Corn	Other	5	nr	1	nr	1	3	2
Sorghum	Cotton	nr	2	nr	nr	nr	13	8
Sorghum	Other	nr	1	nr	1	2	3	3
Soybean	Soybean	nr	5	nr	6	3	nr	1
Soybean	Cotton	nr	2	nr	6	2	1	1
Soybean	Other	nr	2	nr	1	1	1	1
Fallow 1/	Fallow	5	2	1	1	nr	4	3
Fallow	Cotton	4	nr	10	1	1	2	3
Fallow	Other	1	2	nr	nr	nr	2	1
Cotton	Cotton	56	71	50	74	82	56	61
Cotton	Fallow	5	1	*	6	1	1	1
Cotton	Soybean	nr	5	nr	2	2	*	1
Cotton	Other	6	2	11	nr	nr	3	4
Vegetable	Cotton	nr	nr	5	nr	nr	*	1
Vegetable	Vegetable	1	nr	4	nr	1	nr	1
Vegetable	Other	1	nr	2	nr	1	1	*
	Sub-total	84	97	84	98	96	96	96
Other	Other	16	3	16	2	4	4	4
	Total	100	100	100	100	100	100	100

nr = None reported. * = Less than 1 percent. 1/ No crops planted during this year.

Table C-5--Share of acres in commodity support program on land producing cotton in 1990

Previous crop		Cotton program only	Cotton & other commodity program	Non-participation in cotton program 1/
		Million acres planted		
		3.64	4.72	1.40
1989	1988	Percent		
Cotton	Cotton	75	54	45
Sorghum	Any	4	13	16
Corn	Any	1	9	7
Fallow	Any	5	6	5
Cotton	Other	7	5	8
Vegetables	Any	2	1	5
Other		6	12	14
All		100	100	100

1/ Includes cotton land in farms enrolled only in 1990 feed grain, wheat, or rice program.

Fall Potatoes

Fall potatoes are grown from Maine to Washington, and rotations reflect concerns about potato losses from soil-borne organisms, the availability of other crops, and economic conditions in the various potato growing regions.

Less than 5 percent of 1990 potato acreage grew potatoes in the preceding 2 years, unchanged from 1988 (table C-6). Continuous potato production, however, remained popular in New York (31 percent) and Michigan (20 percent). The shares of acreage were somewhat higher in both States compared to 1988.

The most common crops planted prior to the potatoes are wheat, barley, and corn. Twenty percent of the 1990 potato acreage grew wheat in the preceding year, mostly in Minnesota, North Dakota, Colorado, and Idaho. Led by Washington, Oregon, Michigan, and Pennsylvania, 10 percent of the 1990 potato acreage grew corn the previous year. A potato-barley-potato cropping pattern was prevalent in Colorado, where 43 percent of potato acreage followed this pattern. A significant regional barley demand for beer production makes this an attractive crop in rotation with potatoes.

Table C-6--Common crop rotations used on land producing potatoes, 1990

Previous crop 1989	1988	CO	ID	ME	MI	MN	NY	ND	OR	PA	WA	WI	1990 area
		Million acres planted											
		0.07	0.40	0.08	0.03	0.07	0.02	0.15	0.05	0.02	0.13	0.07	1.10
		Percent											
Corn	Corn	nr	*	nr	5	6	2	9	4	8	18	1	5
Corn	Fallow	nr	nr	nr	nr	nr	nr	nr	17	3	9	nr	2
Corn	Potatoes	nr	nr	3	10	nr	2	nr	nr	3	4	2	1
Corn	Other	nr	1	nr	7	2	nr	3	7	3	5	6	2
Wheat	Corn	nr	*	nr	nr	2	nr	1	3	nr	5	nr	1
Wheat	Wheat	4	10	nr	nr	23	nr	11	3	nr	1	nr	6
Wheat	Barley	nr	1	nr	nr	4	nr	4	nr	nr	nr	nr	1
Wheat	Fallow 1/	nr	1	nr	nr	4	nr	3	1	nr	3	nr	1
Wheat	Potatoes	13	11	nr	nr	4	2	7	6	5	nr	nr	6
Wheat	Other	nr	5	nr	nr	9	nr	20	9	3	1	nr	5
Barley	Wheat	nr	2	nr	nr	16	nr	7	3	nr	nr	nr	2
Barley	Barley	4	4	nr	nr	3	nr	1	10	nr	nr	nr	3
Barley	Potatoes	43	13	3	nr	nr	nr	nr	6	2	nr	nr	8
Barley	Other	2	3	nr	nr	5	2	5	3	nr	nr	nr	2
Fallow	Fallow	nr	19	3	2	3	2	nr	5	3	8	6	9
Fallow	Potatoes	nr	8	1	5	nr	7	nr	nr	8	7	4	5
Fallow	Other	nr	5	1	2	1	2	4	nr	3	6	6	4
Alfalfa	Alfalfa	nr	7	2	5	nr	5	nr	10	3	10	5	6
Alfalfa	Other	nr	nr	3	5	nr	5	nr	nr	11	3	7	2
Oats	Potatoes	nr	nr	35	[illegible]	nr	17	nr	nr	14	nr	2	4
Oats	Other	2	nr	1	nr	nr	nr	nr	nr	3	nr	1	[illegible]
Potatoes	Oats	nr	nr	19	2	nr	nr	nr	nr	2	nr	nr	2
Potatoes	Potatoes	7	nr	9	20	2	31	nr	1	nr	nr	6	3
Potatoes	Other	21	1	10	[illegible]	nr	2	nr	2	8	1	6	4
Vegetable	Vegetable	nr	nr	nr	3	1	10	nr	nr	nr	6	20	3
Vegetable	Potatoes	nr	nr	5	2	1	5	nr	nr	3	nr	2	1
Vegetable	Other	nr	1	nr	4	nr	nr	nr	1	2	4	14	2
	Sub-total	96	92	95	88	87	94	86	93	87	92	88	92
Other	Other	4	[illegible]	5	12	13	6	14	7	13	8	12	[illegible]
	Total	100	100	100	100	100	100	100	100	100	100	100	100

nr = None reported. 1/ No crops planted during this year.

Similar to 1988, two regional rotation patterns were observed in 1990. Maine, New York, Pennsylvania, and Michigan grew significant amounts of oats prior to potatoes in 1990. Colorado, North Dakota, Minnesota, Idaho, Oregon, and Washington growers grew wheat and barley prior to potatoes. Alfalfa production was also common among potato growers in Washington, Idaho, Oregon, and Wisconsin. Other vegetable crops were grown on 22 percent of the potato acreage in Wisconsin.

Fallowing is often practiced to conserve moisture and to interrupt disease and insect cycles such as golden nematode, late blight, common scab, corky ring spot, and verticillium wilt. Eighteen percent of the 1990 potato acreage was left idle in 1989. Idaho (32 percent) and Washington (32 percent), were extensive users of fallowed land for 1990 potato production.

Rice

The most common cropping patterns in the two major rice producing States are rice-soybeans-soybeans and rice-soybeans-rice. The shares of 1990 rice acres using the rice-soybeans-soybeans pattern were 31 percent in Arkansas and 29 percent in Louisiana (table C-7). With both States combined, 31 percent of the 1990 rice acreage was planted to soybeans during the previous 2 years; another 22 percent was planted to soybeans in 1989 and rice in 1988. Overall, 61 percent of the 1990 rice acres grew soybeans in 1989.

Continuous rice production was more common in Louisiana (13 percent) than Arkansas (4 percent). In 1990, 20 percent of the rice acres grew rice in the previous year, while 10 percent was fallowed. There was little change in crop rotation practices in these 2 States compared to previous years.

Crop rotations are effective in controlling rice weeds, insects, and diseases. The most common rice weeds requiring control are red rice and barnyardgrass. These weeds reduce the yield and quality of the rice (17). The quality and yield of U.S. rice is reduced an estimated 15 percent each year by weeds. The most damaging pests are rice stink bug and rice water weevil, which reduce production an estimated 4 percent a year. Armyworms also damage rice crops (2,17).

Table C-7--Cropping patterns used on land producing rice, 1990

Previous crop 1989	Previous crop 1988	AR	LA	1990 area
		Millon acres planted		
		1.23	0.57	1.80
		Percent		
Sorghum	Soybean	3	nr	2
Sorghum	Rice	2	nr	1
Soybean	Soybean	31	29	31
Soybean	Fallow	6	3	5
Soybean	Rice	22	22	22
Soybean	Other	4	1	3
Fallow	Soybean	3	3	3
Fallow 1/	Rice	4	8	5
Fallow	Fallow	1	5	2
Fallow	Other	*	nr	*
Rice	Soybean	9	8	9
Rice	Fallow	3	1	3
Rice	Rice	4	13	7
Rice	Other	1	1	1
Sub-total		93	94	94
Other	Other	7	6	6
Total		100	100	100

nr = None reported. 1/ No crops planted during this year.

Spring Wheat

Land used for spring wheat production in 1990 showed a variety of cropping patterns, reflecting primarily the availability of moisture in the major producing States. The most common cropping practice was wheat-fallow-wheat. Montana, with 55 percent of its 1990 acres under this cropping practice, remained the leading State (table C-8). For all surveyed States combined, 31 percent of the 1990 spring wheat crop was grown on land left idle in the preceding year. The second most popular cropping pattern was continuous spring wheat production. Thirteen percent of 1990 spring wheat acres followed continuous wheat production pattern.

In most of the surveyed States, 1990 spring wheat was preceded by barley on 4 to 10 percent of the acreage. Where rainfall or irrigation permitted, more input-intensive crops were grown in the year preceding spring wheat production. In Minnesota, 28 percent of the spring wheat acres were planted to soybeans in the preceding year, while in South Dakota, corn preceded wheat on 25 percent of the 1990 spring wheat acreage.

North Dakota is the major durum wheat producer. Forty-three percent of the State's acreage planted to durum wheat in 1990 had been fallow in 1989 (table C-8). This cropping practice reflects the moisture constraint farmers face in this area. Only 15 percent of 1990 acres in North Dakota were planted to wheat the previous 2 years.

For both spring and durum wheat acreage, the amount of acreage planted to wheat for two or more years has increased and the acreage of wheat following fallow has declined since 1988. This change reflects the decline in Acreage Reduction Program (ARP) levels from 1988 through 1990 as well as the 1990 wheat program provision which allowed producers to plant up to 105 percent of their base.

Table C-8--Cropping patterns used on land producing spring and durum wheat, 1990

Previous crop		Spring wheat					Durum wheat
1989	1988	MN	MT	ND	SD	Area	ND
		2.80	2.80	8.00	2.20	15.80	3.10
				Percent			
Corn	Other	11	nr	2	25	7	1
Soybean	Corn	7	nr	nr	6	2	nr
Soybean	Wheat	11	nr	3	10	5	nr
Soybean	Other	10	nr	1	6	3	2
Barley	Other	10	5	8	4	8	1
Fallow 1/	Wheat	3	55	15	4	18	28
Fallow	Barley	nr	6	4	nr	3	3
Fallow	Other	4	13	11	6	10	12
Wheat	Wheat	16	11	12	15	13	15
Wheat	Fallow	7	6	10	8	9	12
Wheat	Other	7	nr	12	4	9	5
Sunflower	Wheat	nr	nr	6	nr	3	2
Sunflower	Other	nr	nr	1	2	1	nr
Drybeans	Other	6	nr	6	nr	4	nr
Sub-total		92	96	91	90	95	81
Other	Other	8	4	9	10	5	19
Total		100	100	100	100	100	100

nr = None reported. 1/ No crops planted during this year.

Conclusion

Comparison between 1989 and 1990 crop production patterns for the major field crops showed very little overall change. Cropping Practices Survey data for 1990 indicate while farmers continue to extensively practice crop rotations, monoculture cropping is still prevalent in certain crops and States such as cotton in the southern States and corn in the irrigated area of Nebraska. The distribution of cropping patterns differed significantly between three farm program participation categories for 1990 corn and cotton acres. For both crops, a larger share of land in farms enrolled solely in the feed grains or cotton programs was continuously cropped than for land not enrolled in either of these programs. However, a large share (23 percent for corn and 45 percent for cotton) of land not participating in either program was also cropped continuously.

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